A Reference Wetland Network for Assessment and Monitoring of Montana's Herbaceous Wetlands

Prepared for:

U. S. Environmental Protection Agency

Prepared by:

Karen R. Newlon and Linda K. Vance

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Executive Summary

Wetlands provide critical biological and economic benefits such as plant and wildlife habitat, flood attenuation, and groundwater recharge, yet these systems are experiencing increasing pressures from human activities such as urbanization, agricultural development, and land conversion. Several states have expended considerable effort in the development of wetland assessment and monitoring programs to collect information on ambient wetland condition. Such programs are essential to determining the success and effectiveness of conservation and restoration of these resources. An important step in the development of any assessment and monitoring strategy is the establishment of a reference wetland network. A reference wetland network is a collection of wetland sites representing a gradient of condition and serves several purposes. It establishes a basis for defining what comprises a characteristic level of integrity for a given wetland system. It also establishes the range and variability of multiple wetland attributes. Additionally, it provides a real world representation of multiple wetland systems representing a range of condition that can be monitored and reassessed to effectively track changes over time, in terms of both improvement and degradation.

The goal of this project was to establish a statewide reference wetland network representing Montana's herbaceous wetland ecological systems across a condition gradient. We wanted to identify the variability in multiple wetland attributes that influence wetland condition. Additionally, we wanted to identify anthropogenic disturbances that potentially influence wetland condition. We followed the U.S. EPA's recommended three-tiered framework. We conducted a GIS-based analysis (Level 1) to characterize the anthropogenic disturbances potentially impacting wetland condition using available digital data; rapid field-based wetland assessments (Level 2) that assess wetland condition based on observable field indicators; and intensive assessments (Level 3) to collect detailed information on vegetation composition and cover.

We targeted wetlands representing Montana's herbaceous wetland systems across the Northwestern Glaciated Plains, Northwestern Great Plains, Middle Rockies, Canadian Rockies, and the Northern Rockies Level III ecoregions with the goal of selecting wetlands that occur along a disturbance gradient. A targeted approach to sampling was used to ensure that the wetlands selected represented both the full gradient of disturbance and the appropriate wetland ecological systems. For descriptive purposes, we chose ecological systems as our typology. Ecological systems are groupings of biological communities occurring in similar physical environments, and influenced by similar ecological processes such as flooding, fire, wind, and snowfall.

For each wetland site, we conducted a Level 1 GIS-based assessment within a 100-m envelope around the selected wetland site. We conducted a rapid assessment (Level 2) using an approach developed by the Montana Natural Heritage Program (MTNHP). The assessment endpoint of the MTNHP Rapid Assessment Method (RAM) is wetland ecological condition, which is defined as the degree to which a wetland departs from full ecological integrity. RAMs are based on the assumption that the condition of a wetland will vary predictably along a disturbance gradient and the resulting condition can be evaluated using a core set of visible field indicators or metrics. The role of the RAM is to transfer information about the condition of multiple wetland

ecological attributes (e.g., landscape context, hydrology) into overall levels of wetland condition. To capture information on potential causes of disturbances, we incorporated a stressor checklist that recorded both stressors present at the site as well as stressors occurring within a 500-m envelope around the site.

At a subsample of wetland assessment sites, we conducted intensive (Level 3) assessments. The MTNHP uses vegetation as an intensive measure to assess wetland condition and to validate both the Level 1 landscape analysis and the Level 2 rapid assessments. Vegetation was selected because wetland plants are often good indicators of the cumulative impacts of disturbances on wetland condition.

For Level 1 and Level 2 assessment scores, we calculated descriptive statistics and assessed the range and distribution of each metric by examining frequency histograms. We also calculated Spearman's correlation coefficients of Level 2 attribute scores and final ecological integrity scores to determine relationships between Level 2 attribute and overall scores and Level 1 metrics. For Level 3 assessments, we calculated multiple vegetation metrics to conduct a floristic quality assessment (FQA). The FQA accounts for the presence of both native and exotic species, as well as individual plant species' tolerance of and sensitivity to disturbance. We determined the relationship between our Level 3 vegetation metrics and our Level 2 assessment scores by examining Spearman's correlation coefficients. We also examined the relationship between our Level 3 metrics and our site level stressor checklist as well as our Level 1 assessment results to assess the response of vegetation to disturbance.

We conducted 237 Level 1 landscape assessments and Level 2 rapid wetland assessments across Montana. Examination of frequency histograms revealed little variability among Level 1 landscape metrics across all sites. Only local and secondary roads and evidence of livestock use showed a range of values. Both attribute scores and overall scores for Level 2 assessments were generally lower for sites assessed in the Northwestern Glaciated Plains and Northwestern Great Plains ecoregions than those assessed in the three Rocky Mountain ecoregions. We grouped attribute and overall wetland condition scores into four categories: 90-100, 80-89, 70-79, and <70. In the Plains, most Great Plains Prairie Potholes and Western Great Plains Saline Depressions had Overall Condition scores of > 80. However, most Western Great Plains Depressional Wetlands scored between 70 and 89. In the Rockies, most sites had Overall Wetland Condition scores of > 90 for all ecological systems.

Vegetation metrics were highly variable across the wetland ecological systems. FQI indices were higher for the Great Plains Prairie Pothole, Rocky Mountain Alpine-Montane Wet Meadow, and Rocky Mountain Subalpine-Montane Fen ecological systems. Fens had consistently higher values for all vegetation metrics except those associated with exotic species. Western Great Plains Depressional Wetland and Western North American Emergent Marsh ecological systems generally had the lowest values for all FQI metrics. Depressional wetlands of the Great Plains had higher percentages of exotic species.

In general, wetland condition was negatively correlated with roads and cropland/agriculture in the surrounding envelope for wetlands of the Northwestern Great Plains and the Northwestern Glaciated Plains ecoregions. Temporary and seasonal wetlands showed the strongest relationships with disturbance. Condition scores for Great Plains wetlands were also significantly correlated with several of our Level 3 vegetation metrics.

Additionally, several vegetation metrics had significant negative correlations with site-level stressors. For wetland systems of the Rockies, we observed several significant negative relationships between our Level 2 attribute scores and Level 1 metric scores. However, Rocky Mountain Subalpine-Montane Fens showed few significant relationships, as many of the sites in this system had few landscape-level disturbances. Condition scores for Rocky Mountain wetlands were also significantly correlated with several Level 3 vegetation metrics, although this varied based on hydroperiod. Several Level 3 vegetation metrics had a significant negative relationship with several site-level disturbances, although this also varied with hydroperiod.

Despite our efforts to target wetlands representing the full range of condition, we found that wetlands within the Northwestern Glaciated Plains and the Northwestern Great Plains generally scored lower than wetlands within the Middle Rockies, Canadian Rockies, and Northern Rockies across all Level 2 attributes. Nearly all wetlands in the Plains are associated with roads, typically local or secondary roads. Additionally, many wetlands in the Plains are in a matrix of dryland agriculture. Moreover, the condition of the buffer surrounding many of these wetlands has been compromised by a conversion of native grassland to non-native species to provide forage for livestock or dense nesting cover to enhance waterfowl habitat. During periods of drought or prolonged dry phases within the wet-dry cycle, these species encroach into depressional wetlands, negatively influencing the biotic structure and composition of these wetlands.

Most of our vegetation metrics responded as we predicted to indicators of wetland disturbance, but only for stressors recorded in the field. Similarly, relationships between Level 1 disturbance metrics and our Level 2 scores were weak. The Level 1 GIS-based assessment, while providing a broad characterization of disturbances within a landscape context, was not suitable for use as a disturbance gradient. Only roads were consistently related to Level 2 scores and Level 3 vegetation metrics, indicating that our current Level 1 metrics are not good predictors of wetland condition. We will continue to refine our disturbance index by collecting detailed quantitative data on stressors at each site where Level 3 vegetation data are also collected.

Results from our Level 2 wetland assessments allow for a rapid comparison of wetland condition both within and across ecological systems. They also provide a useful method to diagnose potential causes of wetland degradation and to identify potential solutions, providing a useful tool to inform management decisions. Additionally, our reference network provides examples of multiple wetland systems in varying levels of condition across the state, promoting a broader understanding of our wetland resources. Specifically, it identifies that wetland systems in the Northwestern Great Plains of Montana may be particularly vulnerable to disturbance, illustrating the need to focus and prioritize conservation, acquisition, and restoration efforts on these systems.

Acknowledgements

This project was funded by an Environmental Protection Agency Region 8 Wetland Program Development Grant. We would like to thank Toney Ott and Jill Minter of EPA Region 8 for their support and commitment to wetland assessment and monitoring in our region. We thank the many dedicated individuals who spent long days in the field collecting data for this project, including Catherine McIntyre, Natalie Byars, Tara Luna, Jessica Clarke, Larissa Pfleeger, and Eva Masin. Randy Apfelback, Lynda Saul, and Stephen Carpenedo of MT DEQ provided feedback and advice on the field protocol. Joanna Lemly of the Colorado Natural Heritage Program provided helpful suggestions for data analysis. Allan Cox and Meghan Burns of MTNHP developed the webpage for this project. Coburn Currier of MTNHP formatted and edited the final version of this report. Any errors or omissions in the report are entirely the responsibility of the authors.

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Introduction

Wetlands provide critical biological and economic benefits such as plant and wildlife habitat, flood attenuation, and groundwater recharge, yet these systems are experiencing increasing pressures from human activities such as urbanization, agricultural development, and land conversion (Kentula et al. 2004). Several states have expended considerable effort in the development of wetland assessment and monitoring programs to collect information on ambient wetland condition (Mack 2001, Jacobs 2007, Collins et al. 2008). Such programs are essential to determining the success and effectiveness of conservation and restoration of these resources. Additionally, research on compensatory mitigation programs suggests that the federal goal of no-net-loss is not being met, in part due to lack of wetland monitoring (National Research Council 2001). Wetland assessments can provide the necessary tools to evaluate the effects of mitigation and restoration practices, target wetland restoration and conservation efforts, and track the impact of land use decisions (Fennessy et al. 2007, Wardrop et al. 2007, Jacobs et al. 2010).

An important step in the development of any assessment and monitoring strategy is the establishment of a reference wetland network (U.S. EPA 2008). A reference wetland network is a collection of wetland sites representing a gradient of condition. The highest point along this gradient is termed reference standard. Reference standard can be defined one of two ways. The first definition is minimally disturbed condition (MDC), which describes condition in the presence of minimal human disturbance and is likely the best approximation of ecological integrity (Stoddard et al. 2006). The second definition is least disturbed condition (LDC; sensu Stoddard et al. 2006), which describes the best attainable condition given the state of the landscape. The criteria for LDC will vary regionally because the best available condition is dependent upon the disturbances present in the landscape.

A reference wetland network serves several purposes. It establishes a basis for defining what comprises a characteristic level of integrity for a given wetland system. It also establishes the range and variability of multiple wetland attributes. Additionally, it provides a real world representation of multiple wetland systems representing a range of condition that can be monitored and reassessed to effectively track changes over time, in terms of both improvement and degradation (Rheinhardt et al. 2007, Faber-Langendoen et al. 2008).

The goal of this project was to establish a statewide reference wetland network representing Montana's herbaceous wetland ecological systems across a condition gradient. We wanted to identify the variability in multiple wetland attributes that influence wetland condition. Additionally, we wanted to identify anthropogenic disturbances that potentially influence wetland condition. We followed the U.S. EPA's recommended three-tiered framework. We conducted a GIS-based analysis (Level 1) to characterize the anthropogenic disturbances potentially impacting wetland condition using available digital data; rapid field-based wetland assessments (Level 2) that assess wetland condition based on observable field indicators; and intensive assessments (Level 3) to collect detailed information on vegetation composition and cover.

Study Area

We targeted wetlands representing Montana's herbaceous wetland systems (Appendix A) across the Northwestern Glaciated Plains, Northwestern Great Plains, Middle Rockies, Canadian Rockies, and the Northern Rockies Level III ecoregions (Figure 1; Omernik 1987).

Northwestern Glaciated Plains Ecoregion

Vegetation

The Northwestern Glaciated Plains ecoregion extends from the foothills of the Rocky Mountains eastward. This area coincides with the extent of continental glaciation. The topography is gently rolling prairie with a relatively high concentration of depressional wetlands. The wetlands are primarily of glacial origin and are comprised of several wetland ecological systems, including Great Plains Prairie Pothole, Western Great Plains Saline Depression, Western Great Plains Closed Depression, and Western Great Plains Open Freshwater Depression Wetland. Vegetation in these wetlands occurs largely along a hydrologic gradient, with plant communities occurring as concentric bands directly related to zones of inundation (van der Valk 1989). Drier, temporarily flooded wetlands have an outer vegetation zone dominated by western wheatgrass (*Pascopyrum smithii*) and an inner zone of foxtail barley (*Hordeum jubatum*). With longer inundation periods, seasonally flooded wetlands have an outer zone of foxtail barley and an inner zone dominated by common spikerush (*Eleocharis palustris*). Semi-permanently flooded wetlands retain water into late summer and typically support hydrophytic vegetation such as hardstem bulrush (*Schoenoplectus acutus*) and cattail (*Typha latifolia*). Wetlands in areas of increased soil salinity support halophytic species such as Nuttall's alkaligrass (*Puccinellia nuttalliana*), saltgrass (*Distichlis spicata*), red swampfire (*Salicornia rubra*), and Pursh seepweed (*Suaeda calceoliformis*) in drier saline sites, and cosmopolitan bulrush (*Schoenoplectus martimus*) and common threesquare (*S. pungens*) in sites with longer hydroperiods.

Upland vegetation within the Northwestern Glaciated Plains ecoregion is characterized by short- and mid-grass prairie species including needle-and-thread (*Hesperostipa comata*), green needlegrass (*Nassella viridula*), blue grama (*Bouteloua gracilis*), and western wheatgrass.

Soils

Within the Northwestern Glaciated Plains ecoregion, soils are generally deep and range in texture from loamy to clayey. Soils are largely frigid Borolls, Ustochrepts, Natriborols, and Orthents (McNab and Avers 1994).

Climate

The climate in the Northwestern Glaciated Plains ecoregion is cold continental with dry winters and warm summers. Maximum precipitation occurs in spring and early summer. Winters are extremely cold with strong, desiccating winds (McNab and Avers 1994). Climate data from the Western Regional Climate Center (2010) provides summary statistics as follows: average annual precipitation ranges from 282 mm in Havre, Montana (years of record: 1961-2009) to 342 mm in Wolf Point, Montana (years of record: 1905-2009). Over the last 10-15 years, however, average annual precipitation has been lower across the region (Havre: 251 mm, 1996-2008; Wolf Point: 299 mm, 1998-2008). Average maximum summer temperatures in Havre range from 76.5 ºF to 85.3 ºF (24.7 ºC to 29.6 ºC) in Havre and from 80.3 ºF to 88.9 ºF (26.8 ºC to 31.6 ºC) in Wolf Point.

Northwestern Great Plains Ecoregion

Vegetation

The Northwestern Great Plains ecoregion is largely unglaciated and generally drier than the Northwestern Glaciated Plains ecoregion. Topography is generally rolling but occasional breaks, buttes, and badlands occur throughout the region (Woods et al. 1999). Wetlands in this ecoregion are most often associated with springs and seeps and small to medium perennial and

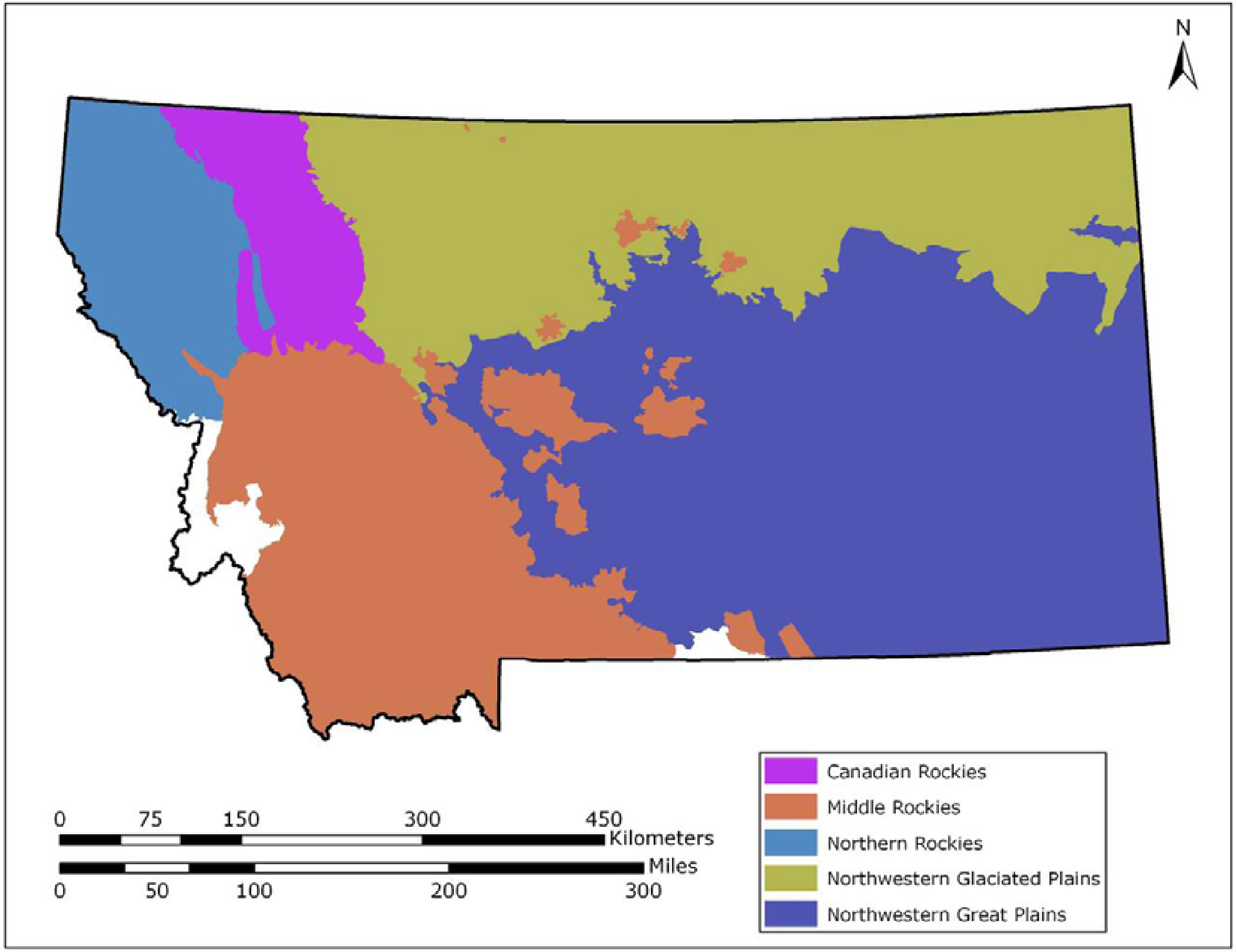

Figure 1. Level III ecoregions included in the Montana Reference Wetland network.

intermittent streams (Stagliano 2005). Vegetation composition is largely determined by inundation, with hardstem bulrush and cattail occurring in the wettest zones, and manna grass (*Glyceria* spp.), sedges (*Carex* spp.), spikerush, and western wheatgrass in drier zones.

Upland vegetation is similar to that of the Northwestern Glaciated Plains except greater portions of this ecoregion are comprised of sagebrush steppe communities dominated by Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis*). Other common shrub species include silver sagebrush (*Artemisia cana*) and greasewood (*Sarcobatus vermiculatus*).

Soils

Within the Northwestern Great Plains ecoregion, soils are moderately deep to deep with loamy to clayey textures. In the northern, southern, and eastern portion of this ecoregion, soils are mostly mesic and frigid Borolls and Ustolls. In the central and western portion of this ecoregion and along breaks and badlands, soils range from shallow to deep and generally have clayey textures (McNab and Avers 1994).

Climate

The climate in the Northwestern Great Plains ecoregion is cold continental with dry winters and warm summers. Maximum precipitation occurs in spring and early summer. Winters are extremely cold with strong, desiccating winds (McNab and Avers 1994). Climate data are from the Western Regional Climate Center (WRCC 2010): average annual precipitation ranges from 317 mm in Roundup, Montana (years of record: 1914-2009) to 383 mm in Ekalaka, Montana (years of record: 1896-2009). Average maximum summer temperatures in Roundup range from 78.9 ºF to 88.9 ºF (26 ºC to 31.6 ºC) in Roundup, and from 76.5 ºF to 86 ºF (24.7 ºC to 30 ºC) in Ekalaka.

Middle Rockies Ecoregion

Vegetation

The Middle Rockies Ecoregion comprises much of the southwestern portion of Montana as well as the island mountain ranges of central and eastern Montana. The topography is generally steep with high elevation mountain ranges largely covered by coniferous forests and foothills dominated by grasslands and shrublands. Wetlands within this ecoregion are diverse in their hydrology and landscape position. Herbaceous wetland ecological systems consist of Rocky Mountain Alpine-Montane Wet Meadow, Rocky Mountain Subalpine-Montane Fen, and Western North American Emergent Marsh. Wetland vegetation in these systems is highly variable and dependent upon hydrology and soils. Wet meadows have surface water for only brief periods early in the growing season. Soils are largely mineral, and vegetation in this system is dominated by graminoids including various sedge and rush (*Juncus* spp.) species. Fens are unique systems having groundwater as the primary hydrologic input. We define fens as having at least 40 cm of organic soil (peat). Vegetative composition within fens varies markedly depending upon soil and water chemistry (Chadde et al. 1998). Fens in the Middle Rockies ecoregion are generally poor fens with low pH and low calcium concentrations. Vegetation is largely graminoids with several sedge species common, including water sedge (*C. aquatilis*), mud sedge (*C. limosa*), Northwest Territory sedge (*C. utriculata*), and inflated sedge (*C. vesicaria*). Other common graminoids include fewflower spikerush (*E. quinqueflora*), tufted hairgrass (*Deschampsia cespitosa*), and reedgrasses (*Calamagrostis* spp.). Emergent marshes in this ecoregion are primarily adjacent to large waterbodies although marshes can also occasionally occur along slow-moving rivers. Marshes are also graminoid dominated with species such as cattail, reed canarygrass (*Phalaris arundinacea*), and coarse sedges such as Northwest Territory sedge and wheat sedge (*C. atherodes*) being most common.

Upland vegetation is characterized by sagebrush steppe, with mountain big sagebrush (*A. t.* ssp. *vaseyana*), Idaho fescue (*Festuca idahoensis*), and bluebunch wheatgrass (*Pseudoroegneria spicata*) on south- and east-facing slopes. North- and west-facing slopes are comprised of coniferous forests with Douglas-fir (*Pseudotsuga menziesii*), lodgepole pine (*Pinus contorta*), and limber pine

(*P. flexilis*). Ponderosa pine (*P. ponderosa*) is common in the northern portion of this ecoregion. Aspen (*Populus tremuloides*) occurs within snowmelt drainages and along toeslopes.

Soils

Soils within the Middle Rockies ecoregion range from relatively shallow to moderately deep with loamy to sandy textures in the mountains, to moderately deep to deep with loamy to clayey textures in the valley bottoms (McNab and Avers 1994). Soils include frigid and cryic Ochrepts, Boralfs, and Borolls with some Fluvents and Aquepts in alluvial valley bottoms.

Climate

The climate of the Middle Rockies ecoregion is cold, dry continental. Most of the precipitation falls as snow and occurs in late fall, winter, and spring (McNab and Avers 1994). Precipitation varies across this ecoregion. Average annual precipitation in Helena, Montana is 301 mm (years of record: 1893-2009); in Dillon, Montana is 333 mm (years of record 1895-2009); and in Bozeman is 469 mm (years of record: 1892-2009). Average maximum summer temperatures range from 72.7 ºF to 83 ºF (22.6 ºC to 28.3 ºC) in Helena; 74.2 ºF – 83.3 ºF (23.4 ºC to 28.5 ºC) in Dillon; and Bozeman 71.6 ºF to 81.3 ºF (22 ºC to 27.3 ºC; WRCC 2010).

Canadian Rockies Ecoregion

Vegetation

The Canadian Rockies ecoregion extends into northern Montana from Alberta and British Columbia. Mountains are generally higher and more snow-covered than the Northern Rockies ecoregion (see below). Portions of this ecoregion are strongly influenced by maritime air masses (Woods et al. 1999). Herbaceous wetlands in this ecoregion are similar to those found in the Middle Rockies ecoregion, although fens in the Canadian Rockies ecoregion are typically rich fens with slightly higher pH and calcium concentrations than those in the Middle Rockies ecoregion. As a result, species diversity in these fens tends to be higher. Common sedge species include mud sedge and slender sedge (*C. lasiocarpa*). Forb diversity can be rich and includes buckbean (*Menyanthes trifoliata*), marsh grass of Parnassus (*Parnassia palustris*), and purple marshlocks (*Comarum palustre*). Several Montana Plant Species of Concern can be found in these fens including adder's tongue (*Ophioglossum pusillum*), English sundew (*Drosera anglica*), and Northern bog clubmoss (*Lycopodium inundatum*).

Upland vegetation includes Douglas-fir, Engelmann's spruce (*Picea engelmannii*), and subalpine fir (*Abies lasiocarpa*) in the mountains with occasional large aspen patches. Foothills are dominated by prairie with rough fescue (*Festuca campestris*) commonly occurring.

Soils

Soils in the Canadian Rockies ecoregion are generally shallow to moderately deep with loamy to sandy textures. Soils include frigid and cryic Ochrepts, Boralfs, Orthents, and Borolls with Fluvents occurring in basins (McNab and Avers 1994).

Climate

The climate of the Canadian Rockies ecoregion is cold, continental with most precipitation falling in spring through early summer. During the winter, severe chinook winds result in dramatic temperature fluctuations (McNab and Avers 1994). Average annual precipitation in West Glacier, Montana is 749 mm (years of record: 1949-2009). Average maximum summer temperatures range from 71.4 ºF to 79.9 ºF (21.9 ºC to 26.6 ºC; WRCC 2010).

Northern Rockies Ecoregion

Vegetation

The Northern Rockies ecoregion is mountainous and rugged and has a strong maritime influence that affects both the vegetation and climate. Herbaceous wetlands consist of wet meadows, fens, and emergent marshes. Of note, high concentrations of vernal ponds occur within this ecoregion in the Seeley-Swan Valley. These ponds provide the only known habitat for the federally listed threatened water howellia (*Howellia aquatilis*) in Montana (Mincemoyer

2005). For this project, we treat these ponds as either Western North American Emergent Marsh or Rocky Mountain Alpine-Montane Wet Meadow, depending upon water permanence. However, these ponds may also be considered Rocky Mountain Wooded Vernal Pool (Vance et al. 2010). Fens in this ecoregion are often extremely rich fens with high pH (>7) and high calcium concentrations (Chadde et al. 1998). Fens in the Swan, Stillwater, and Flathead valleys are typically underlain by limestone and have numerous rich and extremely rich fens (Chadde et al. 1998, Greenlee 1999).

Upland vegetation is primarily coniferous forest, with Douglas-fir, western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), and grand fir (*Abies grandis*). Ponderosa pine is also common at lower elevations. Foothills are dominated by grasslands with rough fescue, bluebunch wheatgrass, and Idaho fescue.

Soils

In the mountains, soils are generally shallow to moderately deep with loamy to sandy textures. Soils include frigid and cryic Ochrepts, Boralfs, and Orthents (McNab and Avers 1994). In the valleys, soils are moderately deep to deep with loamy to sandy textures consisting of Borolls, Ochrepts, Xerolls, Psamments, and Fluvents. Most of the soils have been strongly influenced by volcanic ash (McNab and Avers 1994).

Climate

The climate is cool, temperate with a maritime influence (McNab and Avers 1994). Average annual precipitation is 398 mm in Kalispell (years of record: 1899-2009) and 532 mm in Seeley (years of record: 1936-2009). Average maximum summer temperatures range from 71.1 ºF to 80.9 ºF (21.7 ºC to 27.1 ºC) in Kalispell, and 71.3 ºF to 82 ºF (21.8 ºC to 27.8 ºC; WRCC 2010) in Seeley.

Methods

Site Selection and Field Methods

We targeted sampling of herbaceous wetland ecological systems across Montana (Table 1) with the goal of selecting wetlands that occur along a disturbance gradient. A targeted approach to sampling was used to ensure that the wetlands selected represented both the full gradient of disturbance and the appropriate wetland ecological systems (U.S. EPA 2002, Mack 2007). Each wetland was classified by ecological system (Comer et al. 2003), Cowardin system, class, and water regime (Cowardin et al. 1979), and hydrogeomorphic (HGM) features (Brinson et al. 1993). For descriptive purposes, we chose ecological systems. Ecological systems are groupings of biological communities occurring in similar physical environments, and influenced by similar ecological processes such as flooding, fire, wind, and snowfall. The ecological system concept was developed to provide a mappable unit that could be classified from aerial or satellite imagery and that would be easily identifiable in the field by land managers, resource specialists, and planners (Comer et al. 2003). Systems typically occur on a landscape at scales of tens to thousands of acres, and generally persist in a recognizable state for 50 or more years.

Table 1. Herbaceous wetland ecological systems targeted for wetland assessments in the development of Montana's Reference Wetland Network.

Herbaceous Wetland Ecological Systems
Western Great Plains Open Freshwater Depression Wetland
Western Great Plains Closed Depression Wetland
Western Great Plains Saline Depression Wetland
Great Plains Prairie Pothole
Rocky Mountain Alpine-Montane Wet Meadow
Rocky Mountain Subalpine-Montane Fen
American Emergent Marsh

For each wetland site, we conducted a Level 1 GIS-based assessment within a 100-m envelope around the selected wetland site. We derived landscape level indicators of disturbance from available digital datasets including land cover/land use, hydrology, and roads (Table 2). Given the lack of detailed up-to-date spatial data on livestock grazing and resource extraction, we examined 1-m resolution aerial imagery for evidence of either disturbance. We considered four major attributes as possible sources of anthropogenic disturbances: transportation, hydrology, land cover/land use, and resource use, and each attribute was comprised of multiple metrics (Table 3). We assigned a rating to each metric based upon its distance from the wetland envelope perimeter for transportation, hydrology, and resource use. For land cover/land use, we assigned metric ratings based upon the percent cover of each land cover type within the 100-m envelope. Disturbance ratings increased with either decreasing distance from the disturbance, or increasing percent cover of each land cover type.

We conducted a rapid assessment (Level 2) using an approach developed by the Montana Natural Heritage Program (MTNHP). The rapid assessment method (RAM) is based on the Ecological Integrity Assessment (EIA) framework developed by NatureServe (Faber-Langendoen et al. 2008). The assessment endpoint of the MTNHP RAM is wetland ecological condition, which is defined as the degree to which a wetland departs from full ecological integrity (Fennessy et al. 2007). Ecological integrity is defined as the ability of a system to support and maintain a community of organisms with the species composition, diversity, and functional organization comparable to the natural or historical condition of that system (Karr and Dudley 1981, U.S. EPA 2002). Comparison of attributes of current condition relative to historical or natural variation provides a benchmark for gauging the influence of anthropogenic disturbances on wetland condition (Stoddard et al. 2006). However, knowledge of historical or natural conditions is limited and inference to other areas and ecosystems must be made with caution. As a result, condition scores must be reviewed and updated as additional information is gathered on the historic or natural variation of ecosystem responses.

Table 2. Data sources for each Level 1 assessment metric.

Attribute	Metric	Data Source
Transportation	Distance to 4-wheel drive roads	ftp://ftp2.census.gov/geo/tiger/TIGER2009/
	Distance to local roads	ftp://ftp2.census.gov/geo/tiger/TIGER2009/
	Distance to highways	ftp://ftp2.census.gov/geo/tiger/TIGER2009/
Hydrology	Distance to wells	http://nris.state.mt.us/nsdi/nhd/hiresgeo.asp
	Distance to canals or ditches	http://nris.state.mt.us/nsdi/nhd/hiresgeo.asp
Land Cover	Percent of envelope in crop/agriculture	ftp://nris.mt.gov/MSDI_Landcover.zip
	Percent of envelope in hay/pasture	ftp://nris.mt.gov/MSDI_Landcover.zip
	Percent of envelope in developed, open space	ftp://nris.mt.gov/MSDI_Landcover.zip
	Percent of envelope in low density residential	ftp://nris.mt.gov/MSDI_Landcover.zip
	Percent of envelope in medium density residential	ftp://nris.mt.gov/MSDI_Landcover.zip
Soils	Soil type	http://nris.mt.gov/nrcs/soils/datapage.asp
Climate	Relative effective annual precipitation	http://nris.mt.gov/nrcs/REAP/datapage.asp
Wetland characteristics	Wetland polygon size	http://nris.state.mt.us/nsdi/nris/shape/nwi_poly.zip
	Perimeter to area ration of wetland polygon	http://nris.state.mt.us/nsdi/nris/shape/nwi_poly.zip
	Distance to nearest five wetlands	http://nris.state.mt.us/nsdi/nris/shape/nwi_poly.zip

Table 3. Level 1 assessment attributes and associated metrics and metric ratings.

Attribute	Metric	Distance from Perimeter (meters)	Rating
Roads	4x4, dirt	> 200	1
		> 100 - 200	2
		0 - 100	3
	local, city	>300	1
		>200-300	2
		>100-200	3
		0-100	4
	highways	>500	1
		>300-500	2
		>200-300	3
		>100-200	4
		0-100	5
Land Cover/ Land Use	medium density residential	<5%	1
		5%-15%	2
		>15%-20%	3
		>20%-30%	4
		>30%	5
	Low density residential / high use recreation	<=10%	1
		>10%-25%	2
		>25%-40%	3
		>40%	4
	developed/open space	<=10%	1
		>10%-25%	2
		>25%-40%	3
		>40%	4
	crop agriculture	<5%	1
		5%-15%	2
		>15%-25%	3
		>25%-40%	4
		>40%	5
	hay pastures	<=10%	1
		>10%-25%	2
		>25%-40%	3
		>40%	4

Table 3. Level 1 assessment attributes and associated metrics and metric ratings (Con't).

Attribute	Metric	Distance from Perimeter (meters)	Rating
Hydrology	canals, ditches	>200	1
		>100-200	2
		0-100	3
	upstream reservoirs (includes cattle stockponds)	>1,000	1
		>500-1,000	2
		>200-500	3
		0-200	4
	wells	>200	1
		>100-200	2
		0-100	3
Resource Use	resource extraction	>1,000	1
		>500-1,000	2
		>200-500	3
		0-200	4
	evidence of livestock use	>200	1
		>100-200	2
		0-100	3

The RAM integrates the biological and physical processes that maintain a particular system. RAMs are based on the assumption that the condition of a wetland will vary predictably along a disturbance gradient and the resulting condition can be evaluated using a core set of visible field indicators or metrics (Sutula et al. 2006). These metrics are a qualitative or quantitative measurement of a physical or biological attribute (e.g., vegetation structure and composition) and consist of narrative ratings representing a range of condition.

The MTNHP RAM consists of five attributes and associated metrics (Table 4). Each metric is scaled along a gradient reflecting wetland condition as compared to a relatively undisturbed state. An understanding of how each metric responds to anthropogenic disturbance is necessary to determine condition thresholds. The farther a particular indicator or metric shifts from a relatively undisturbed state, the lower the rating it would receive. The RAM uses three to five rating categories to describe the status of each metric relative to a relatively undisturbed state. Metric ratings are assigned on an ordinal scale (Appendix B). The role of the RAM is to transfer information about the condition of multiple wetland ecological attributes (e.g., landscape context, hydrology) into overall levels of wetland condition, so each metric rating is rolled up into an overall attribute score. The attribute scores are then combined into an overall condition score. See Appendix C for scoring procedures.

To capture information on potential causes of disturbances, we incorporated a stressor checklist that recorded both stressors present within the assessment area (AA) as well as stressors occurring within a 500-m envelope around the AA. The stressor checklist has a similar structure to the RAM attributes (e.g., stressors relating to hydrology, landscape context; Appendix B). Stressor checklists can provide additional information when evaluating ecological integrity and can provide further understanding of overall wetland condition. In some cases, stressors may be present at or near a site, but condition metrics may not reflect these impacts. This may be caused by a temporal lag between the impact and its effect on the biotic community, such as a very recent clear

Table 4. The Montana Natural Heritage Program Rapid Assessment Method attributes and component metrics.

Attribute	Metric
Landscape Context	Landscape Connectivity
	Buffer Width
	Buffer Length
	Buffer Condition
Size	Wetland Size Relative to Historic Conditions
Biotic Structure and Composition	Relative Cover of Native Plant Species
	Relative Cover of Tolerant Native Plant Species
	Cover of Noxious Plant Species
	Organic Matter Accumulation
	Patch Interspersion
Hydrology	Water Source
	Hydroperiod
	Hydrologic Connectivity
Physicochemical	Soil Surface Integrity
	Water Quality

cut. Or it may reflect stressors that the current biotic metrics do not pick up. In the first case, the stressor checklist can be used to flag sites that may become degraded in the future. In the second case, the stressor checklist may indicate that adjustments should be made to the metrics. Observed stressors were marked off on the checklist and tallied to create a disturbance gradient (Miller and Wardrop 2006). The assumption being that the more stressors present at a site, the greater the level of disturbance.

At each sample point, we established an assessment area (AA), defined as all wetland area of the same ecological system type within a 0.5 hectare area around the sample point. We determined the extent of the AA by first estimating the approximate boundaries of the wetland within the potential AA. Readily observable ecological criteria such as vegetation, soil, and hydrological characteristics were used to define wetland boundaries, regardless of whether they met jurisdictional criteria for wetlands regulated under the Clean Water Act. Second, we delineated the ecological system present within the wetland boundary. Because certain field metrics varied by ecological system, the AA included a single ecological system where possible. Rapid assessments generally took less than two hours to complete.

At a subsample of wetland assessment sites, we conducted intensive (Level 3) assessments. The MTNHP uses vegetation as an intensive measure to assess wetland condition and to validate both the Level 1 landscape analysis and the Level 2 rapid assessments (Wardrop et al. 2007). Vegetation was selected because wetland plants are often good indicators of the cumulative impacts of disturbances on wetland condition (Cronk and Fennessy 2001). In addition, vegetation can be assessed in all types of wetlands including those that only have standing water seasonally. Other forms of intensive assessments such as water quality, diatoms, and macroinvertebrates require standing water throughout the growing season. Our vegetation sampling techniques differed depending upon the wetland system sampled. In the depressional wetlands of the Northwestern Glaciated and Northwestern Great Plains ecoregions, we collected vegetation data using a quadrat method modified from DeKeyser et al. (2003). We placed seven to 15 evenly distributed 1 m^2 quadrats from the central vegetation zone spiraling out into the wet meadow and low prairie zones (Figure 2).

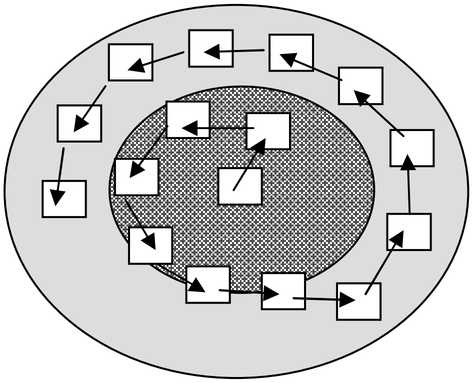

Figure 2. Quadrat layout used to sample vegetation in depressional wetlands (modified from DeKeyser et al. 2003).

In the Middle Rockies, Canadian Rockies, and Northern Rockies ecoregions, we collected data on vegetation composition and cover using a 20 m x 50 m relevé plot (Peet et al. 1998). The structure of the plot consisted of ten 10 m x 10 m (100 m2) modules typically arranged in a 2 x 5 array (Figure 3). The plot was subjectively placed within the AA to maximize abiotic/biotic heterogeneity to capture micro-site variations produced by hummocks, water tracks, side-channels, pools, wetland edge, and microtopography.

We estimated absolute cover of all vascular species within four of the 100 m2 modules, referred to as "intensive" modules. We also estimated the area covered by standing water, bare ground, litter, and bryophytes for each module. When all species within a module were identified, cover was visually estimated for the 100 m2 module using the following cover classes (Peet et al. 1998):

1 = trace (one individual)
2 < 1%
3 ≥ 1–2%
4 ≥ 2–5%
5 ≥ 5–10%
6 ≥ 10–25%
7 ≥ 25–50%
8 ≥ 50–75%
9 ≥ 75–95%
10 ≥ 95%

After sampling each of the intensive modules, we walked through the remaining, or residual, modules to document presence of any species not recorded in the intensive modules. Percent cover of these species was estimated over the entire 1,000 m2 plot. We used cover class midpoints to calculate average values for each taxon at each plot.

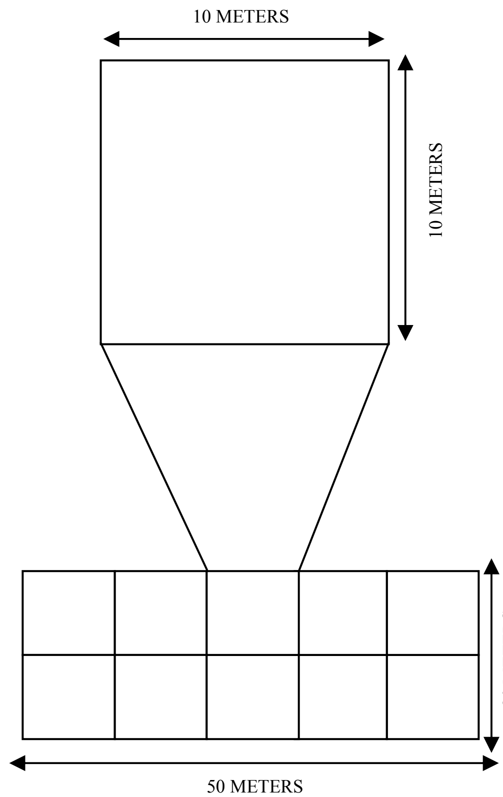

Figure 3. Reléve plot layout (adapted from Peet et al. 1998).

At a subsample of sites, we also conducted rapid assessments using the Montana Department of Environmental Quality (MTDEQ) Wetland Rapid Assessment Method to compare results between our EIA approach and the MTDEQ method.

Data Analysis

Level 1 Assessments

We calculated descriptive statistics and assessed the range and distribution of each metric by examining frequency histograms. We created correlation matrices using Spearman's correlation coefficients to investigate relationships and evaluate redundancy among metrics. Similarly, we calculated Spearman's correlation coefficients of Level 2 attribute scores and final ecological integrity scores to determine relationships between Level 2 attribute and overall scores and Level 1 metrics.

Level 2 Assessments

We calculated descriptive statistics and assessed the range and distribution of each metric by examining frequency histograms. We created correlation matrices using Spearman's correlation coefficients to investigate relationships and to evaluate any redundancy among metrics. Similarly, we calculated Spearman's correlation coefficients of attribute scores and final wetland condition scores to determine the amount of variability explained by each attribute and each metric.

Level 3 Assessments

We calculated multiple vegetation metrics (Appendix D) to conduct a floristic quality assessment (FQA). Several studies have demonstrated the effectiveness of the FQA in assessing wetland condition (Lopez and Fennessy 2002, DeKeyser et al. 2003, Jones 2004, Hargiss et al. 2008). The FQA accounts for the presence of both native and exotic species, as well as individual plant species' tolerance of and sensitivity to disturbance (Cronk and Fennessy 2001, Miller and Wardrop 2006). We assigned coefficients of conservatism (C-values) to all plant species recorded and identified to species (Northern Great Plains Floristic Quality Assessment Panel 2001, Jones 2005, Rocchio 2007). C-values represent the relative tolerance of a species to disturbance, ranging from 0 to 10. Native species that exhibit high degrees of ecological specificity and sensitivity to disturbance have C-values of 9-10. Native species that are typical of well established communities that have undergone minimal disturbance have C-values of 7-8. Native species that have some degree of habitat specificity but can tolerate moderate disturbance have C-values of 4-6. Widespread native species that occur in a variety of communities and are common in disturbed sites have values of 1-3. Finally, exotic species were assigned C-values of 0.

Based on a review of the literature, we made predictions regarding the response of each vegetation metric to increasing human disturbance (Table 5).

We determined the relationship between our Level 3 vegetation metrics and our Level 2 assessment scores by examining Spearman's correlation coefficients. We also examined the relationship between our Level 3 metrics and our site level stressor checklist as well as our Level 1 assessment results to assess the response of vegetation to disturbance. All analyses were conducted in R 2.10.1 (R Core Development Team 2009).

Table 5. Vegetation metrics and their predicted responses to increasing human disturbance.

Vegetation Metric	Predicted Response to Increasing Human Disturbance
Mean C-value of native species	decrease
Mean C-value of all species	decrease
Number of exotic species	increase
Number of native species	decrease
Number of all species	decrease
Percent exotic species	increase
Cover weighted mean C-value of native species	decrease
Cover weighted mean C-value of all species	decrease
Floristic quality index (FQI)	decrease
FQI of native species	decrease
Cover weighted FQI of all species	decrease
Cover weighted FQI of native species	decrease
Adjusted FQI of all species	decrease
Adjusted cover weighted FQI of all species	decrease

Results

Wetland Assessments

We conducted 237 Level 1 landscape assessments and Level 2 rapid wetland assessments across Montana (Figure 4). Examination of frequency histograms revealed little variability among Level 1 landscape metrics across all sites (Appendix E). Only local and secondary roads and evidence of livestock use showed a range of values.

Both attribute scores and overall assessment scores were generally lower for sites assessed in the Northwestern Glaciated Plains and Northwestern Great Plains ecoregions than those assessed in the three Rocky Mountain ecoregions (Table 6).

We grouped attribute and overall wetland condition scores into four categories: 90-100, 80-89, 70-79, and <70 (Appendix F). The following describes the trends of scores across the ecological systems.

Landscape Context

For wetlands assessed in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions, Landscape Context attribute scores varied by wetland ecological system. Great Plains Prairie Potholes generally scored > 90 for the Landscape Context attribute, whereas Western Great Plains Depressional Wetlands had nearly a third of sites scoring < 70 and most Western Great Plains Saline Depression Wetlands scored < 70 for this attribute. Most wetlands in the Middle, Canadian, and Northern Rockies ecoregions scored > 90 for this attribute although scores were variable.

Relative Size

The Relative Size attribute showed virtually no variability across wetland systems.

Biotic Composition and Structure

For all three wetland systems in the Plains ecoregions, most sites scored < 70 for the Biotic Composition and Structure attribute. In contrast, most wetlands in the Rockies scored > 80 for this attribute although scores varied by ecological system. Most Subalpine-Montane Fens scored > 90, while most Western North American Emergent Marshes scored between 80 and 89. This is largely due to the prevalence of cattails, which are included in the Tolerant Native metric. Scores for Rocky Mountain Alpine-Montane Wet Meadows were highly variable. These wetlands typically have a shorter hydroperiod, and tolerant native species and exotic species can more readily establish in these wetlands.

Table 6. Average rapid wetland assessment (Level 2) scores for sites in the Montana Reference Wetland Network.

Ecological System	*N*	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
Great Plains Prairie Pothole	*39*	88	91	71	98	87	**87**
Western Great Plains Saline Depression Wetland	*16*	71	92	70	95	96	**85**
Western Great Plains Open Freshwater Depression Wetland	*24*	73	90	66	81	76	**77**
Western Great Plains Closed Depression Wetland	*7*	79	96	68	95	95	**87**
Western Great Plains Depressional Wetland*	*31*	75	91	66	84	80	**79**
Rocky Mountain Alpine-Montane Wet Meadow	*60*	83	95	80	94	91	**89**
Western North American Emergent Marsh	*40*	80	98	81	91	93	**89**
Rocky Mountain Subalpine-Montane Fen	*20*	78	96	91	96	91	**90**

* Western Great Plains Depressional Wetland contains both open and closed depression systems.

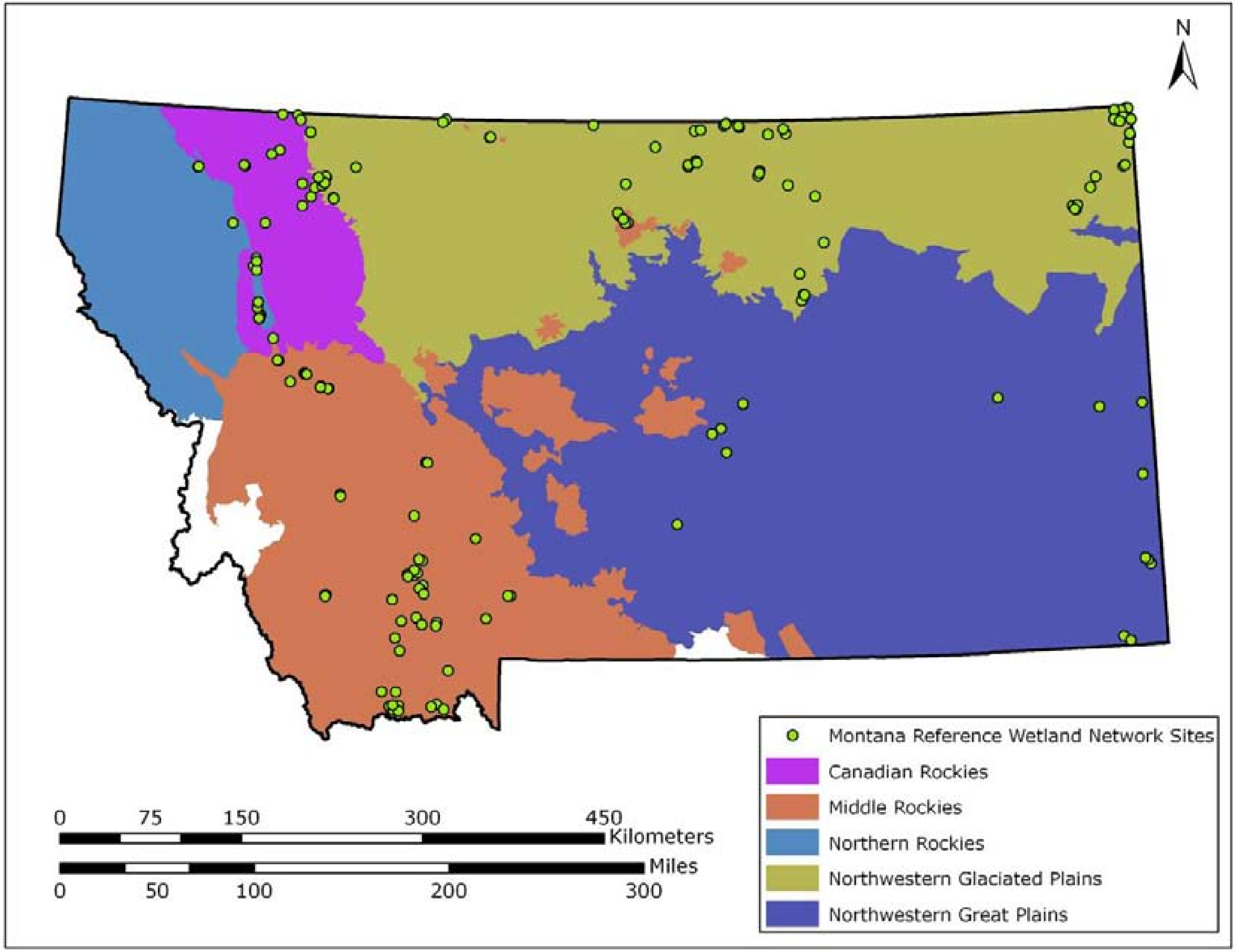

Figure 4. Montana Reference Wetland network sites by Level III ecoregion..

Hydrology

For all three wetland systems in the Plains ecoregions, most sites scored > 90 for the Hydrology attribute, although Western Great Plains Depressional Wetlands showed the greatest variability. For sites in the Rockies, most sites scored > 90 across all ecological systems.

Physicochemical

In the Plains, most Great Plains Prairie Potholes and Western Great Plains Saline Depressions scored > 90 for the Physicochemical attribute. However, most Western Great Plains Depressional Wetlands scored < 90 for this attribute, and nearly a third of the sites scored < 70. For wetlands in the Rockies, most sites scored > 90 for this attribute.

Overall Wetland Condition

In the Plains, most Great Plains Prairie Potholes and Western Great Plains Saline Depressions had Overall Condition scores of > 80. However, most Western Great Plains Depressional Wetlands scored between 70 and 89. In the Rockies, most sites had Overall Wetland Condition scores of > 90 for all ecological systems.

Level 3 Vegetation Measurements

Vegetation metrics were highly variable across the wetland ecological systems (Table 7). Although mean C-values were similar across the systems, FQI indices were higher for the Great Plains Prairie Pothole, Rocky Mountain Alpine-Montane Wet Meadow, and Rocky Mountain Subalpine-Montane Fen ecological systems. Fens had consistently higher values for all vegetation metrics except those associated with exotic species. Western Great Plains Depressional Wetland and Western North American Emergent Marsh ecological systems generally had the lowest values for all C-value and FQI metrics. Depressional wetlands of the Great Plains had higher percentages of exotic species.

Examination of vegetation metric values for depressional systems of the Plains ecoregions by Cowardin water regime revealed higher values for all native species vegetation metrics with increasing hydroperiod and lower values for exotic species metrics (Table 8). Wetlands with longer hydroperiods generally had fewer exotic species.

For wetlands in the Rockies ecoregions, the relationship between vegetation metrics and hydroperiod was highly variable (Table 9). Saturated wetlands, typically associated with fens, had the highest native species vegetation metric values.

Results from our validation analyses can be found in Appendix G. In general, wetland condition was negatively correlated with roads and cropland/

Table 7. Values for vegetation metrics calculated for herbaceous wetland ecological systems.

Vegetation Metrics	Western Great Plains Depressional Wetland (*n* =14)	Great Plains Prairie Pothole (*n* =9)	Rocky Mountain Alpine-Montane Wet Meadow (*n=26*)	Western North American Emergent Marsh (*n* =5)	Rocky Mountain Subalpine-Montane Fen (*n* =14)
Mean C-value of native species	5.3	5.5	5.2	4.6	5.7
Mean C-value of all species	3.4	3.8	4.6	4.1	5.2
Number of exotic species	3.0	4.0	2.0	1.4	3.1
Number of native species	7.0	10.0	13.5	9.6	29.0
Number of all species	10.0	14.0	15.6	11.0	32.1
Percent exotic species	35.4	32.0	11.4	10.6	9.3
Adjusted FQI of native species	42.2	44.8	49.1	43.4	54.8
Adjusted cover weighted FQI of native species	41.4	44.7	45.9	40.3	53.7
Cover weighted mean C-value of native species	5.1	5.4	4.8	4.3	5.6
Cover weighted mean C-value of all species	4.1	4.5	4.3	3.6	5.4
FQI	10.8	14.5	17.1	13.6	28.7
FQI of native species	13.5	16.9	18.3	14.4	30.4
Cover weighted FQI of all species	13.2	16.6	15.8	12.1	29.5
Cover weighted FQI of native species	13.3	17.0	17.0	13.2	29.5

Table 8. Values for vegetation metrics for depressional wetland systems of the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions by Cowardin water regime.

Vegetation Metric	Temporary (n =12)		Seasonal (n =11)		Semi-permanent (n =9)	
	Average	SD	Average	SD	Average	SD
Mean C-value of native species	5.0	0.7	5.9	0.7	6.2	0.5
Mean C-value of all species	3.0	1.0	4.8	1.8	5.1	1.2
Number of exotic species	3.9	2.1	2.1	2.2	2.3	2.0
Number of native species	5.4	3.0	8.6	3.7	13.6	5.3
Number of all species	9.3	3.7	10.7	3.1	15.9	6.4
Percent exotic species	42.9	17.7	20.3	22.9	14.2	11.5
Adjusted FQI of native species	37.4	8.0	52.7	13.5	57.6	7.0
Adjusted cover weighted FQI of native species	34.9	7.1	51.0	13.6	56.7	5.8
Cover weighted mean C-value of native species	4.7	0.7	5.7	0.9	6.1	0.5
Cover weighted mean C-value of all species	3.3	0.9	5.4	1.1	5.5	0.8
FQI	9.1	4.3	15.5	6.3	20.1	6.5
FQI of native species	11.4	4.0	17.1	5.2	22.7	5.6
Cover weighted FQI of all species	10.1	3.8	17.5	5.0	21.6	4.7
Cover weighted FQI of native species	10.7	3.8	16.7	5.5	22.3	5.0

Table 9. Values for vegetation metrics for herbaceous wetland systems of the Middle Rockies, Northern Rockies, and Canadian Rockies ecoregions by Cowardin water regime.

Vegetation Metric	Temporary (n =9)		Saturated (n =13)		Seasonal (n =10)		Semi-permanent (n =5)	
	Average	SD	Average	SD	Average	SD	Average	SD
Mean C-value of native species	4.3	0.3	5.8	0.9	4.7	0.9	4.5	1.1
Mean C-value of all species	3.4	0.9	5.5	1.2	4.1	1.1	4.0	0.6
Number of exotic species	2.7	2.6	1.7	2.1	3.0	4.1	0.8	1.0
Number of native species	10.7	3.9	26.9	12.4	17.6	11.5	5.5	4.4
Number of all species	13.3	4.9	28.6	13.1	20.6	13.7	6.3	5.3
Percent exotic species	18.8	17.4	5.3	6.1	12.5	12.2	8.6	10.2
Adjusted FQI of native species	38.3	5.8	56.8	10.4	43.7	10.3	42.2	8.6
Adjusted cover weighted FQI of native species	34.6	7.0	54.7	16.3	43.4	15.6	39.5	11.6
Cover weighted mean C-value of native species	3.8	0.5	5.6	1.6	4.6	1.4	4.2	1.5
Cover weighted mean C-value of all species	2.9	1.3	5.5	1.7	4.0	1.7	3.5	0.9
FQI	12.1	3.2	28.7	8.1	17.6	7.3	9.8	5.4
FQI of native species	13.7	2.8	29.5	8.9	18.8	7.7	10.5	6.0
Cover weighted FQI of all species	10.3	4.0	28.3	10.2	16.9	6.9	9.0	6.4
Cover weighted FQI of native species	12.2	2.1	28.3	9.8	18.2	7.6	9.8	5.8

agriculture in the surrounding envelope for wetlands of the Northwestern Great Plains and the Northwestern Glaciated Plains ecoregions. Temporary and seasonal wetlands showed the strongest relationships with disturbance. Condition scores for Great Plains wetlands were also significantly correlated with several of our Level 3 vegetation metrics. Additionally, several vegetation metrics had significant negative correlations with site-level stressors. For wetland systems of the Rockies, we observed several significant negative relationships between our Level 2 attribute scores and Level 1 metric scores. However, Rocky Mountain Subalpine-Montane Fens showed few significant relationships, as many of the sites in this system had few landscape-level disturbances. Condition scores for Rocky Mountain wetlands were also significantly correlated with several Level 3 vegetation metrics, although this varied based on hydroperiod. Several Level 3 vegetation metrics had a significant negative relationship with several site-level disturbances, although this also varied with hydroperiod.

Discussion

Despite our efforts to target wetlands representing the full range of condition, we found that wetlands within the Northwestern Glaciated Plains and the Northwestern Great Plains generally scored lower than wetlands within the Middle Rockies, Canadian Rockies, and Northern Rockies across all Level 2 attributes. Nearly all wetlands in the Plains are associated with roads, typically local or secondary roads. Additionally, many wetlands in the Plains are in a matrix of dryland agriculture. Moreover, the condition of the buffer surrounding many of these wetlands has been compromised by a conversion of native grassland to provide forage for livestock or dense nesting cover to enhance waterfowl habitat. Dense nesting cover often consists of non-native species including alfalfa (*Medicago sativa*), smooth brome (*Bromus inermis*), and sweet clover (*Melilotus* spp.). During periods of drought or prolonged dry phases within the wet-dry cycle, these species encroach into depressional wetlands, negatively influencing the biotic structure and composition of these wetlands. Additionally, we found some evidence that wetlands with a longer hydroperiod may be more resilient to wetland disturbances.

The greatest impact to the Physicochemical condition of wetlands across all ecological systems was compaction and pugging of soils by livestock, which affects vegetation establishment and regeneration and soil drainage. Western Great Plains Depressional Wetlands had the lowest Physicochemical attribute scores, reflecting the propensity for cattle to concentrate in these sensitive areas. These wetlands are relatively isolated on the landscape and as a result are typically the focus of both hydrologic alterations (e.g., impoundments to create stock reservoirs) and livestock use.

Although wetland size is considered an important indicator of condition for some systems (Collins et al. 2008), the Relative Size attribute was not useful in evaluating wetland condition and showed little variability in attribute scores. Moreover, it was not assessed reliably in the field and has since been dropped from our assessment methods.

An initial goal of this project was to assess the ability of the MTDEQ Wetland Rapid Assessment Method to assess wetland condition. Rapid assessment results were similar between the MTNHP RAM and the MTDEQ Wetland Rapid Assessment Method and results from both methods were significantly correlated with a number of Level 3 vegetation metrics. However, the MTDEQ assessment method incorporates measures of stress into its final condition score making it difficult to tease out the influence of these stressors on wetland condition. The inclusion of stressors as measures of condition also makes it difficult to directly assess the influence of management practices on these stressors (Sutula et al. 2006).

Most of our vegetation metrics responded as we predicted to indicators of wetland disturbance. However, this was only observed with the examination of stressors recorded in the field. Similarly, relationships between Level 1 disturbance metrics and our Level 2 scores were weak. The Level 1 GIS-based assessment, while providing a broad characterization of disturbances within a landscape context, was not suitable for use as a disturbance gradient. Although Level 1 assessments have provided a reliable assessment of wetland condition in other parts of the country (Hychka et al. 2007, Wardrop et al. 2007, Weller et al. 2007), these methods have been developed in areas with significant levels of land conversion and urbanization. Only roads were consistently related to Level 2 scores and Level 3 vegetation metrics, indicating that our current Level 1 metrics are not good predictors of wetland condition. Because we have very current and comprehensive GIS data layers available in Montana, and have used them in developing and testing Level 1 assessment approaches, we are not confident that Level 1 assessments can substitute for on-the-ground assessments in this part of Montana. The combined effects of drought and site-specific disturbance may override impacts from landscape-level stressors.

Although we did observe several significant correlations between our field-based stressors and our Level 2 scores, we are not accounting

for interactions among stressors that likely have a cumulative impact on wetland condition. For example, a hydrologic stressor such as an impoundment typically is associated with a road and often livestock grazing. We also did not account for the scope or severity of individual stressors. For instance, grazing was recorded as a stressor and received the same score whether there was one cow or 50. It is likely that the magnitude of a particular stressor influences condition more than the type of stressor (DeKeyser et al. 2003). In the future, we will incorporate measures of severity and scope into our stressor measurements.

We had hoped to use this stressor-response relationship to determine specific condition thresholds (*sensu* Jones 2004); however, we did not see a clear pattern in these relationships. We divided our assessment scores into four categories that can be coarsely interpreted as at or near expected reference standard (scores = 90-100), slight departure from expected reference standard (scores = 80-89), moderate departure from expected reference standard (scores = 70–79), and severe departure from expected reference standard (scores < 70). We urge caution in the use of these condition classes, as it is difficult to objectively determine condition thresholds without a) independently assessed reference standard sites or b) a clear stressor-response relationship (J. Van Sickle, U.S. EPA, pers. comm., May 19, 2010). We will continue to refine our disturbance index by collecting detailed quantitative data on stressors at each site where Level 3 vegetation data are also collected. This will improve our ability to define defensible condition thresholds.

Even without specific condition thresholds, results from our Level 2 wetland assessments allow for a rapid comparison of wetland condition both within and across ecological systems. They also provide a useful method to diagnose potential causes of wetland degradation and to identify potential solutions, providing a useful tool to inform management decisions. Additionally, our reference network provides examples of multiple wetland systems in varying levels of condition across the state, promoting a broader understanding of our wetland resources. Specifically, it identifies that wetland systems in the Northwestern Great Plains of Montana may be particularly vulnerable to disturbance, illustrating the need to focus and prioritize conservation, acquisition, and restoration efforts on these systems.

The reference network has also allowed us to refine and calibrate our wetland assessment methods. Additionally, the reference network can be used to refine and validate other assessment methodologies, as well as help to establish wetland water quality standards. The network can also provide a means to track variability over time and to evaluate the performance of wetland protection and restoration projects.

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Appendix A. Herbaceous Wetland Ecological System Descriptions

Western Great Plains Closed Depressional Wetland

General Description
This system includes a variety of depressional wetlands generally found in complexes in central and eastern Montana. This type of wetland differs from Western Great Plains Open Depressional Wetlands and Great Plains Prairie Potholes by being completely isolated from both the regional groundwater system and inter-wetland surface drainage systems. They occur in depressional basins found in flat, enclosed upland areas or on level shallow lake basins. The major sources of input water are precipitation and snow melt, and water loss occurs through evapotranspiration. The basins are typified by the presence of an impermeable layer, such as dense clay formed in alluvium that is poorly drained. Subsurface soil layers are restrictive to water movement and root penetration. Ponds and lakes associated with this system can experience periodic drawdowns during dry years, but are replenished by spring rains. Closed depressions experience irregular hydroperiods, most filling with water only occasionally and drying quickly, influencing the plant communities that are present. The drawdown zone is typically dominated by western wheatgrass (*Pascopyrum smithii*) and foxtail barley (*Hordeum jubatum*). Povertyweed (*Iva axillaris*) and willow dock (*Rumex salicifolius*) occupy the broad, low gradient basins which are shallowly inundated in the spring and draw down every year to reveal bottoms of gray bentonite. Common spikerush (*Eleocharis palustris*) occurs within the drawdown area where there is more organic matter in the substrate. Hardstem bulrush (*Schoenoplectus acutus*) typifies closed depressions sufficiently deep to remain permanently inundated during most years. Species richness can vary considerably among individual examples of this system and it is especially influenced by adjacent land use like agriculture and grazing.

Diagnostic Characteristics
lowland, herbaceous, depression, depressional, playa, clay subsoil, impermeable layer, saturated, isolated wetland, strictly isolated wetland

Range
This system can be found throughout the eastern portion of the Western Great Plains; however, it is most prevalent in the central states of Nebraska, Kansas and Oklahoma. In Montana, closed depressions are most concentrated to the north of the HiLine and Route 2, from the Blackfeet Reservation to the North Dakota border. Individual depressions can also be found across the Northwest Glaciated Plains north of the Missouri River.

Environment
This system is typified by depressional basins found in flat enclosed upland areas and level shallow lake basins, with an impermeable layer such as dense clay isolating the wetland from the regional groundwater system. It differs from Western Great Plains Open Depression Wetlands and Great Plains Prairie Potholes by being completely isolated from both the regional groundwater system and inter-wetland surface drainage systems. These wetlands occur in depressional basins found in flat enclosed upland areas or on level shallow lake basins. The major sources of input water are precipitation and snow melt; water loss occurs through evapotranspiration. The basins are typified by the presence of an impermeable layer, such as dense clay formed in alluvium that is poorly drained. Subsurface soil layers are restrictive to water movement and root penetration (Cook and Hauer, 2007). Ponds and lakes associated with this system can experience periodic drawdowns during dry years, but are replenished by spring rains. Closed depressions experience irregular hydroperiods, filling with water only occasionally and drying quickly, which influences the plant communities that are present.

Vegetation
Vegetation within this system is highly influenced by hydrology, salinity, fire and adjacent land uses. The drawdown zone is typically dominated by western wheatgrass (*Pascopyrum smithii*) and foxtail barley (*Hordeum jubatum*), the most common wet meadow component of this landscape. Needle spikerush (*Eleocharis acicularis*) and the small annual forbs slender plantain (*Plantago elongata*) and purslane speedwell (*Veronica peregrina*) are common in most stands. Povertyweed (*Iva axillaris*) and willow dock (*Rumex salicifolius*) occupy the broad, low gradient basins which are shallowly inundated in the spring and draw down every year to reveal bottoms of gray bentonite. The common spikerush (*Eleocharis palustris*) association is also within the drawdown zone but occurs at sites where there is more organic matter in the substrate. Foxtail barley (*Hordeum jubatum*) and needle spikerush (*Eleocharis acicularis*) are typically well represented in drier stands, while water knotweed (*Polygonum amphibium*) stands are found at wetter sites. Marsh vegetation, dominated by hardstem bulrush (*Schoenoplectus acutus*), typifies depressions sufficiently deep to remain permanently inundated during most years. Forbs commonly associated with these marsh communities include water knotweed *(Polygonum amphibium*), common spikerush (*Eleocharis palustris*) and two headed water-starwort (*Callitriche heterophylla*).

Dynamic Processes
These systems developed under Northern Great Plains climatic conditions, which included natural disturbances by large herbivores, periodic flooding events and occasional fire. Wet-drought year climatic cycles in Montana, often in 10 to 20 year intervals, influence the ecological communities in these systems (Hansen et al. 1995). Each year seeds from annuals and perennials germinate and cover exposed mud flats, but when precipitation floods the depressions, the annuals drown and the perennials survive. Over a series of years the perennials dominate. The drawdown to mudflats is necessary so that emergent vegetation can become reestablished. This flooding, drawdown and the eventual exposure of mud flats drive the water-level vegetation cycle.

Management
Changes will occur in the plant communities due to climatic conditions and/or management actions. Due to the nature of the soils, these sites are considered moderately resilient. With continued adverse impacts, a moderate decline in vegetative vigor and composition will occur. Heavy continuous grazing and/or continuous seasonal (spring) grazing, without adequate recovery periods will eventually lead to loss of the Western wheatgrass-foxtail barley wetland community, and inland saltgrass will begin to increase. Western wheatgrass will increase initially, but then will begin to decrease. In time, heavy continuous grazing will cause inland saltgrass, fowl bluegrass (*Poa palustris*), and other pioneer perennials and annuals to increase. This replacement plant community is resistant to change, due to the grazing tolerance of inland saltgrass and increased surface salts. However, a significant amount of production and diversity has been lost compared to the Western wheatgrass -foxtail barley community, and the loss of key cool season grasses and increased bare ground will affect energy flow and nutrient cycling. Water infiltration will be reduced significantly due to the massive shallow root system "root pan" characteristic of inland saltgrass, and the increased amount of bare ground. It will take a long time to bring this plant community back with management alone (USDA NRCS, 2003).

Restoration Considerations
The major barriers to restoration are isolation, infrequent flooding, impermeable soils and invasive species. These factors must be addressed during the planning and long term management of restored wetlands.

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Western Great Plains Open Freshwater Depression Wetland

General Description

This Great Plains system occurs in lowland depressions and along lake borders with open basins and a permanent water source through most of the year. This system is distinguished from the Western Great Plains Closed Depression Wetlands by having a larger watershed and/or significant connection to the groundwater table. Soils are typically Mollisols, Entisols or occasionally Histosols. Soil pH varies from neutral to slightly alkaline. In Montana, this system is especially well represented along major and secondary tributaries of the Milk, Marias and Two Medicine rivers in the northwestern Great Plains glaciated pothole region. Throughout Montana, most sites within this system are found at elevations of 664-2,027 meters (2,180-6,650 feet). Species diversity can be high in some occurrences. These wetlands usually contain emergent graminoids such as cattails (*Typha* species)*,* sedges (*Carex* species), spikerushes (*Eleocharis* species), rushes *(Juncus* species) and bulrushes (*Schoenoplectus* species), as well as floating vegetation such as pondweeds (*Potamogeton* species), arrowhead *(Sagittaria* species), or common hornwort (*Ceratophyllum demersum*). At montane elevations, these systems can be moderately complex with a variety of species and communities. Increased grazing pressure in and adjacent to these systems will change the plant communities that are present. In semi-permanent systems, the drawdown zone is typically dominated by beaked sedge (*Carex utriculata*) water sedge (*Carex aquatilis*), and Nebraska sedge (*Carex nebrascensis*). In seasonal ponds that draw down annually, and in semipermanent wetlands during drought years, buried seeds of both annuals and perennials will germinate in exposed mud flats.

Diagnostic Characteristics
Herbaceous, depression, depressional, saturated soils, partially isolated

Range
This system occurs across the western Great Plains from North Dakota and Kansas west to Montana and south to Texas. This system can occur throughout the western Great Plains but is likely more prevalent in the south-central portions of the division. Its distribution extends into central Montana, where it occurs in the matrix of the Northwestern Great Plains Mixed Grass Prairie. However, these depressions are most concentrated to the north of the Hi-Line and Route 2, from the Blackfeet Reservation to the North Dakota border. Individual depressions can also be found across the Northwest Glaciated Plains north of the Missouri River.

Environment
Open depression wetlands are found throughout the Northwestern Glaciated Great Plains region of Montana. They form in lowlands, and along lake borders and stream margins. They generally have more open basins, a large watershed, and a permanent water source throughout most of the year, except during exceptional drought years. This system differs from closed depressional wetlands by having a larger watershed and/or significant connection to the groundwater table (Cook and Hauer 2007). In Montana, most sites within this system are found at elevations of 664-2,027 meters (2,180-6,650 feet). Soils are typically Mollisols, Entisols or occasionally Histosols. Soil pH varies from neutral to slightly alkaline.

Vegetation
Open depression wetlands often have submerged aquatic plants in the open water zone including common hornwort (*Ceratophyllum demersum*), short spikewater milfoil *(Myriophyllum sibiricum*), and horned pondweed (*Zannichellia palustris*) as well as floating-leaved plants including pondweeds (*Stuckenia* and *Potamogeton* species), white water crowfoot (*Ranunculus aquatilis*) and arrowheads (*Sagittaria* species). The central marsh zone is typically dominated by hardstem bulrush (*Schoenoplectus acutus*), but softstem bulrush (*Schoenoplectus tabernaemontani*), common threesquare (*Schoenoplectus pungens*) and alkali bulrush (*Schoenoplectus maritimus*), often co-dominate. Also found in the marsh zone are cattails (*Typha* species), water knotweed (*Polygonum amphibium*), and hemlock water parsnip (*Sium suave*). The seasonally flooded zones are typically dominated by graminoids including common spikerush *(Eleocharis palustris*), needle spikerush (*Eleocharis acicularis*), American sloughgrass (*Beckmannia syzigachne*), wheat sedge (*Carex atherodes*), foxtail barley (*Hordeum jubatum*), shortawn foxtail (*Alopecurus aequalis*), and water foxtail (*Alopecurus geniculatus*). Open depressional systems are often bordered by wet prairie zones characterized by species such as slimstem reedgrass (*Calamagrostis stricta*), clustered field sedge (*Carex praegracilis*), bluejoint (*Calamagrostis canadensis*) and fowl bluegrass (*Poa palustris*). Open depressions with more alkaline or saline water and soil chemistry will typically be bordered by species such as saltgrass (*Distichlis spicata)*, western wheatgrass (*Pascopyrum smithii)*, and freshwater cordgrass (*Spartina pectinata)*. Sites that have been moderately grazed often have an increase in Baltic rush (*Juncus balticus*), knotted rush (*Juncus nodosus*), foxtail barley (Hordeum jubatum), American sloughgrass (*Beckmannia syzigachne*), and western wheatgrass (*Pascopyrum smithii*).

Dynamic Processes
These systems developed under Northern Great Plains climatic conditions, and experienced the natural influence of large herbivores, periodic flooding events and occasional fire. Wet-drought year climatic cycles in Montana, often in 10 to 20 year intervals, influence the ecological communities (Hansen et al., 1995). Seeds from annuals and perennials germinate and cover exposed mud flats, but when precipitation floods the depressions, the annuals drown and the perennials survive. Over a series of years the perennials dominate. The drawdown to mudflats is necessary so that emergent vegetation can become reestablished. Flooding, drawdown and the eventual exposure of mud flats drive the water-level vegetation cycle. Species richness can vary considerably among individual examples and is especially influenced by adjacent land use. Agriculture may provide nutrient and herbicide runoff. In saline soil wetlands, the increase in precipitation during exceptionally wet years can dilute the salt concentration in the soils, which may allow for less salt-tolerant species to occur.

Management
Changes will occur in the plant communities due to climatic conditions and/or management activities. Conversion to agriculture and pastureland can impact this system when it alters the hydrology of the system.

Restoration Considerations
In open depression wetland systems where water has been drained or diverted, the original hydrology of the system must be restored. If water levels are restored, re-growth and re-colonization from dormant rhizomatous root systems of common emergent species can occur within a few years. Livestock grazing should be controlled to allow regrowth, recolonization and re-sprouting from existing root systems. Many of the characteristic species found in these systems are rhizomatous, and exhibit excellent erosion control properties. In some cases, if hydric soils are heavily altered due to pugging or compaction, addition of organic material may be needed to facilitate vegetation recolonization.

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Great Plains Prairie Pothole

General Description

Prairie potholes occur in shallow depressions scraped out by glaciers in the northern Great Plains of Montana. The region is characterized by a glacial landscape of end moraines, stagnation moraines, outwash plains and lake plains. The glacial drift forms steep to slight local relief with fine-grained, silty to clayey soils. Limestone, sandstone, and shales are the predominant parent materials, and highly mineralized water can discharge from these rocks. The hydrology of this system is complex, and the concentration of dissolved solids results in water that ranges from fresh to extremely saline, with chemical characteristics varying seasonally and annually. Most prairie potholes and associated lakes contain alkaline water, which accumulates rapidly in during spring months, especially when soil frost is sufficiently deep to forestall all infiltration until after the ground thaws. Most water loss occurs through evapotranspiration, which exceeds precipitation during summer months. Vegetation within this system is highly influenced by hydrology, salinity and dynamics. Potholes can vary in depth and duration, which determines the local gradient of plant species. Similarly, species found within individual potholes will be strongly influenced by periodic drought and wet periods. The wettest sites, where water stands through summer, are characterized by hardstem bulrush (*Schoenoplectus acutus*), often occurring as a near monoculture, or with softstem bulrush (*Schoenoplectus tabernaemontani*) or common threesquare (*Schoenoplectus pungens)* along slightly drier margins. In permanently flooded sites, aquatic buttercups (*Ranunculus* species), aquatic smartweeds (*Polygonum* species), pondweeds (*Potamogeton* species) or duckweeds (*Lemna* species) are common. At the drier extremes, pothole vegetation generally occurs in a concentric pattern from a wetter middle dominated by

spikerush (*Eleocharis* species) through a drier ring of foxtail barley (*Hordeum jubatum*) and an outer margin of western wheatgrass (*Pascopyrum smithii*) or thickspike wheatgrass (*Elymus lanceolatus*). Prairie potholes are considered to be the most important breeding habitat for waterfowl in North America, with production estimates ranging from 50% to 80% of the continent's main species. However, the extreme variability in climate and pothole water levels also results in extreme fluctuations in waterfowl populations from year to year. Prairie pothole wetlands also support a diverse assemblage of water-dependent birds.

Diagnostic Characteristics
lowland, herbaceous depressional, pothole, isolated wetland, temperate

Range
In Montana, most prairie potholes are concentrated north of the HiLine and Route 2, from the Blackfeet Reservation to the North Dakota border, although individual potholes occur across the Northwest Glaciated Plains north of the Missouri River. Elsewhere, this system occurs throughout the northern Great Plains from central Iowa northeast to southern Saskatchewan and Alberta. It encompasses approximately 870,000 square kilometers with approximately 80% of its range in southern Canada. It is also prevalent in North Dakota, South Dakota, and northern Minnesota.

Environment
The prairie pothole ecological system is dominated by closed basins that receive irregular inputs of water from the surroundings and export water as groundwater. The climate is characterized by mid-continental temperature and precipitation extremes. The region is distinguished by a thin mantle of glacial drift with overlying stratified sedimentary rocks of the Mesozoic and Cenozoic ages; these form a glacial landscape of end moraines, stagnation moraines, outwash plains and lake plains. The glacial drift is from 30 meters to 120 meters thick and forms steep to slight local relief with fine-grained, silty to clayey soils. Limestone, sandstone, and shales are predominant, and highly mineralized water can discharge from these rocks. Precipitation and runoff from snowmelt are often the principal water sources, with groundwater inflow as a secondary source. Evapotranspiration is the primary source of water loss, with seepage loss secondary. The hydrology of this system is complex, and the concentration of dissolved solids results in water that ranges from fresh to extremely saline, with chemical characteristics varying seasonally and annually. Most prairie potholes and associated lakes contain water that is alkaline (pH >7.4). Surrounding uplands are generally in cropland (small grains), hay, or range.

Prairie potholes are considered to be the most important breeding habitat for waterfowl in North America, with production estimates ranging from 50% to 80% of the continent's main species. However, the extreme variability in climate and pothole water levels also results in extreme fluctuations in waterfowl populations from year to year. Prairie wetlands also support a diverse assemblage of water-dependent birds including Montana species of concern such as the Black-crowned Night-Heron (*Nycticorax nycticorax*), White-faced Ibis (*Plegadis chihi*), Franklin's Gull (*Larus pipixcan*), Common Tern (*Sterna hirundo*), Forster's Tern (*Sterna forsteri*), and Black Tern (*Chlidonias niger*). American White Pelicans (*Pelecanus erythrorhynchos*) feed extensively on tiger salamanders (*Ambystoma tigrinum*) found in prairie potholes. Sparsely-vegetated alkali potholes, especially in Sheridan County, are attractive to Piping Plovers (*Charadrius melodus*).

Vegetation

Vegetation within this system is highly influenced by hydrology, salinity and dynamics. This system includes elements of emergent marshes and wet, sedge meadows that develop into a pattern of concentric rings. Potholes can vary in depth and duration, which determines the local gradient of species. Similarly, plant species found within individual potholes will be strongly influenced by periodic drought and wet periods. The wettest sites, where water stands into or through summer, are characterized by hardstem bulrush (*Schoenoplectus acutus*), often occurring as a near monoculture, or with a fringe of softstem bulrush (*Schoenoplectus tabernaemontani*) or common threesquare (*Schoenoplectus pungens)* along slightly drier margins. Cattails (*Typha spp*) are also seen in these wetter systems, although they are typically a minor component. During spring or in permanently flooded sites, aquatic buttercups (*Ranunculus* species), aquatic smartweeds (*Polygonum* species), pondweeds (*Potamogeton* species) or duckweeds (*Lemna* species) may be abundant. At the drier extremes, pothole vegetation generally occurs in a concentric pattern from a wetter middle dominated by spikerush (*Eleocharis* species) through a drier ring of foxtail barley (*Hordeum jubatum*) and an outer margin of western wheatgrass (*Pascopyrum smithii*) or thick-spike wheatgrass (*Elymus lanceolatus*) (Hansen et al. 1996, Lesica 1989). Grazing, draining, and mowing of this system can influence vegetation distribution.

Dynamic Processes

Flooding is the primary natural dynamic influencing this system. Snowmelt in the spring often floods this system and can cause the prominent potholes within the system to overflow. Greater than normal precipitation can flood out emergent vegetation and/or increase herbivory by animal species such as muskrats. Periodic wet and droughty periods cause shifts in vegetation. Vegetation zones are evident, and each zone responds to changing environmental conditions. Draining and conversion to agriculture can also significantly impact this system. Much of the original extent of this system has been converted to cropland, and many remaining examples are under pressure to be drained.

Management

Livestock use of potholes is limited by low palatability of characteristic species, although open water attracts livestock for both drinking and cooling. When upland vegetation becomes sparse, cattle will graze on spikerush and bulrush. Wet soils are easily trampled. Grazing, when properly planned and executed, can be a management tool, preventing cattail encroachment into open water, limiting the spread of exotics such as crested wheat (*Agropyron cristatum*) and smooth brome (*Bromus inermis*), and avoiding excessive litter buildup. Prescribed burning can be used to the same ends. Prairie potholes are primarily threatened by crop agriculture, by unrestricted grazing, and by oil and gas development. Region-wide, nearly half of this system has been lost.

Restoration Considerations

In Great Plains prairie pothole wetland systems where water has been drained or altered, the original hydrology of the system must be restored. If water levels are restored, re-growth and re-colonization from dormant rhizomatous root systems of common emergent species can occur within a few years. Many of the characteristic species found in marsh systems are rhizomatous, thus exhibit excellent erosion control properties. However, species that are infrequent in these wetland systems may not re-occur or re-establish in a given time frame. The major barriers to

prairie pothole restoration are isolation, infrequent flooding and invasive species. These factors must be addressed during the planning and long term management of restored prairie pothole wetlands.

During restoration, cattle grazing needs to eliminated or controlled to allow regrowth, recolonization and resprouting from existing root systems. In some cases, if hydric soils are heavily altered due to pugging or compaction, addition of organic material may be needed to facilitate plant recolonization.

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Western Great Plains Saline Depression Wetland

General Description

This ecological system is very similar to both the Western Great Plains Open Freshwater Depression Wetland and the Western Great Plains Closed Depression Wetland found in wetland complexes in the central and northeastern portion of Montana. However, this system differs due to increased soil salinity, which causes these systems to become brackish. This high salinity is attributed to high evaporation and the accumulation of minerals dissolved in the water. Wetlands in this system are discharge wetlands, where water high in dissolved salts has moved from the regional groundwater system into the depression. Hydroperiods vary depending on precipitation and snowmelt, the primary source of water. Water is prevented from percolating out of the depression due to impermeable dense clay, and salt encrustations can occur on the surface with drying. Species that typify this system are salt-tolerant and halophytic graminoids such as alkali bulrush (*Schoenoplectus maritimus*), common three square (*Schoenoplectus pungens*), inland saltgrass (*Distichlis spicata*), Nuttall's alkali grass (*Puccinellia nuttalliana)*, foxtail barley (*Hordeum jubatum*), red swampfire (*Salicornia rubra*) and freshwater cordgrass (*Spartina pectinata*), and shrubs such as black greasewood (*Sarcobatus vermiculatus)*. During exceptionally wet years, an increase in precipitation can dilute the salt concentration in the soils in some cases, allowing for less salt-tolerant species to occur. The distribution of this system extends into central Montana, where it occurs in the matrix of the Northwestern Great Plains Mixed Grass Prairie. However, these depressions are most concentrated to the north of the HiLine and Route 2, from the Blackfeet Reservation to the North Dakota Border. Individual occurrences can also be found across the Northwest Glaciated Plains north of the Missouri River.

Diagnostic Characteristics
Isolated to partially isolated wetland, depression, saline conditions

Range
This system can occur throughout the western Great Plains but is more prevalent in the south-central portions of the division. Its distribution extends into central Montana where it occurs in the matrix of the Northwestern Great Plains Mixed Grass Prairie. These saline depressions are most concentrated to the north of the HiLine and Route 2, from the Blackfeet Reservation to the North Dakota Border. Individual depressions can also be found across the Northwestern Glaciated Plains north of the Missouri River.

Environment
This system is distinguished from the freshwater depression systems by brackish water caused by strongly saline and alkaline soils. This high salinity is attributed to excessive evaporation and the accumulation of minerals dissolved in groundwater discharge. Water is prevented from percolating out of the depression due to an impermeable dense clay soil. Salt encrustations can occur on the surface due to slow water movement (Hansen et al, 1996). On the Blackfeet Indian reservation, water samples collected from saline depressions had conductivity values that ranged from 1,550-40,000 uhmos/cm (Lesica and Shelley, 1988).

Vegetation
Vegetation within this system is highly influenced by soil salinity and soil moisture. Salt-tolerant and halophytic species that typify this system include alkali bulrush (*Schoenoplectus maritimus*), common three square (*Schoenoplectus pungens*), inland saltgrass (*Distichlis spicata*), Nuttall's alkali grass (*Puccinellia nuttalliana*), foxtail barley (*Hordeum jubatum)*, red swampfire (*Salicornia rubra)* and freshwater cordgrass (*Spartina pectinata*), and shrubs such as black greasewood (*Sarcobatus vermiculatus*). Other species include western wheatgrass (*Pascopyrum smithii)* and foxtail barley (*Hordeum jubatum*). Plant zonation related to soil salinity is often apparent in these systems with distinct rings occurring around the fringe of the depression. In deeper, more depressed halophytic habitats, red swampfire or prairie cordgrass will dominate with Nuttall's alkali grass found directly upslope, followed by inland saltgrass. Shrubs such as greasewood and winterfat (*Krascheninnikovia lanata*) are common around the outer margins of this system. Pursh seepweed (*Suaeda calceoliformis*), annual goosefoot (*Chenopodium* species) and seaside arrow-grass (*Triglochin maritima*) are common forbs.

In northeastern Montana, the alkali bulrush association occurs as an emergent band around open water or as zonal vegetation around other plant associations. Water tables are often high, often remaining above the soil surface at least through late summer. Soils are poorly drained, alkaline Entisols. Alkali bulrush forms dense, monotypic stands with up to 91% cover. In some areas along the wetland edge, very minor amounts of common spikerush (*Eleocharis palustris*) may be present. Alkali bulrush can survive periods of total inundation up to 1 meter (3.3 feet) deep, as well as drought periods where the water table remains less than 1 meter below the soil surface. It is a vigorously rhizomatous species that colonizes and spreads when the water table is within 10 centimeters (4 inches) of the surface. Cover of alkali bulrush may be replaced by red swampfire and other associated species during drought years.

Red swampfire occurs in the drawdown zone that is flooded during the early part of the growing season but where the water table drops below soil surface by late spring or early summer. Soils in this zone usually have silty-clay to clay texture, and the soil surface is covered with salt crusts. Principle salts are sulfates and chlorides of sodium and magnesium. It is one of a very few species that can persist in these hyper-saline conditions when the water table drops below the soil surface (Dodd and Coupland 1966).

Dynamic Processes
These systems developed under Northern Great Plains climatic conditions that include natural influence of periodic flooding events and occasional fire. Climate has an important effect on saline areas because precipitation and snowmelt transport salts to the depressions and can dilute the soil solution while temperature and wind influence the rate of evapotranspiration. Increased precipitation and/or runoff can dilute the salt concentration and allow for less salt-tolerant species to occur while increased evapotranspiration increases soil salinity leading to a more brackish habitat type.

Management
Changes will occur in the plant communities due to climatic conditions and/or management activities.

Restoration Considerations
In saline depression wetland systems where water has been drained or altered, the original hydrology of the system must be restored. If hydrology is restored, re-growth and re-colonization from dormant rhizomatous root systems of common emergent species can occur during periods of flooding. Cattle grazing should be deferred or controlled to allow regrowth, recolonization and resprouting from existing root systems. Annuals such as red swampfire and annual goosefoots require periods of inundation and drawdown to initiate germination and to complete their life cycles at the end of the growing season.

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Western North American Emergent Marsh

General Description
This widespread wetland system occurs throughout the arid and semi-arid regions of North America. In Montana, this system is typically found in depressions surrounded by an upland matrix of mixed prairie, shrub steppe, or steppe vegetation. Natural marshes occur in and adjacent to ponds and prairie potholes, as fringes around lakes or oxbows, and along slow-flowing streams and rivers as riparian marshes. Marshes are classified as either seasonal or semipermanent based on the dominant vegetation found in the deepest portion of the wetland; vegetation is representative of the hydroperiod. A central shallow marsh zone dominated by graminoids and sedges characterizes seasonal wetlands, while semipermanent wetlands are continually inundated, with water depths up to 2 meters (6.5 feet) and a deeper central marsh zone dominated by cattails (*Typha* species) and bulrushes (*Schoenoplectus* species). Water chemistry may be alkaline or semi-alkaline, but the alkalinity is highly variable even within the same complex of wetlands. Marshes have distinctive soils that are typically mineral, but can also accumulate organic material. Soils characteristics reflect long periods of anaerobic conditions. Dominant vegetation often includes western wheatgrass (*Pascopyrum smithii*), Northwest Territory sedge (*Carex utriculata*), Nebraska sedge (*Carex nebrascensis*), broadleaf cattail (*Typha latifolia*), and hardstem bulrush (*Schoenoplectus acutus*). Alkaline marsh communities include western wheatgrass, fresh water cordgrass (*Spartina pectinata*), and seashore saltgrass (*Distichlis spicata*).

Diagnostic Characteristics
Herbaceous, depressional, mineral with A horizon greater than 10 cm, aquatic herb, deep water greater than 15 cm, saturated soil

Range
This wetland ecological system occurs throughout western North America. In Montana, it is system is found throughout the state at foothill to upper montane elevations.

Environment
This system is found in environments where precipitation is approximately 25 to 50 centimeters (10 to 20 inches) per year. In Montana, this system is typically found in depressions surrounded by an upland matrix of mixed prairie, shrub steppe, steppe vegetation and forests near the mountains. Natural marshes occur in and adjacent to ponds and prairie potholes, as fringes around lakes or oxbows, and along slow-flowing streams and rivers as riparian marshes. Water chemistry may be alkaline or semi-alkaline, but is highly variable even within the same complex of wetlands. Marshes have distinctive soils that are typically mineral, but can also accumulate organic material. Soils characteristics reflect long periods of anaerobic conditions, with gleying, high organic content, and redoximorphic features. Wetland marshes are classified as either seasonal or semi-permanent based on the dominant vegetation found in the deepest portion of the wetland (Stewart and Kantrud 1971 and LaBaugh et al. 1996). Vegetation communities occurring in these marsh systems is representative of their hydroperiod; some basins dry to bare soil after seasonal flooding, while others will have a variety of wetland types in a zoned pattern dependent on seasonal water table depths and salt concentrations (Kudray and Cooper 2006).

Vegetation
Vegetation communities change according to wet-drought cycles. In seasonal ponds that dry out annually, and in semipermanent wetlands during drought years, buried seeds of both annuals and perennials germinate, covering exposed mud flats (Hansen et al. 1995). In semi-permanent marshes, the drawdown zone is typically dominated by western wheat grass (*Pascopyrum smithii)* near the upland edge, with Northwest Territory sedge (*Carex utriculata*) and Nebraska sedge (*Carex nebrascensis*) as the dominant sedges located down gradient, and broadleaf cattail (*Typha latifolia*) and hardstem bulrush (*Schoenoplectus acutus*) located in the deeper, central portion of the marsh. Water sedge (*Carex aquatilis*) is frequently co-dominant with Northwest Territory sedge. Less commonly, blister sedge (*Carex vesicaria*) and awned sedge (*Carex atherodes*) are intermixed with Northwest Territory sedge or occur as co-dominants on similar sites. Beyond the emergent vegetation, floating-leaved hydrophytes may be present in wetter sites with longer inundation periods, including water lilies (*Nymphaea* species), yellow pondlily (*Nuphar* species), buttercup (*Ranunculus* species) and pondweed (*Potamogeton* species). Other floating species may be present in shallow water, such as duckweed, (*Lemna* species), and submergents such as common hornwort (*Ceratophyllum demersum*), horned pondweed (*Zannichellia palustris*), mare's tail (*Hippuris vulgaris*) and water milfoil (*Myriophyllum* species).

Seasonal marshes are typically dominated by western wheat grass (*Pascopyrum smithii*), beaked sedge (*Carex utriculata*), inflated sedge (*Carex vesicaria*), Nebraska sedge (*Carex nebrascensis*), creeping spikerush (*Eleocharis palustris*), Baltic rush (*Juncus balticus*) and cattail (*Typha latifolia* or *angustifolia*). During wetter years, annuals disappear and marshes become dominated by

emergent perennials. Common perennial forbs include common willow herb (*Epilobium ciliatum*), marsh cinquefoil (*Potentilla palustris*), Gmelin's buttercup (*Ranunculus gmelinii*), greater creeping spearwort (*Ranunculus flammula*), hemlock water parsnip (*Sium suave*), willow dock (*Rumex salicifolius*), field mint (*Mentha arvensis),* leafy aster (*Symphyotrichum foliaceum)* and broadleaf arrowhead (*Sagittaria latifolia*). Fern allies such as water horsetail (*Equisetum fluviatile*) and field horsetail (*Equisetum arvense*) often form significant cover within seasonal marshes. Grasses common to marshes include small floating mannagrass (*Glyceria borealis*), tufted hairgrass (*Deschampsia caespitosa*), and bluejoint reedgrass (*Calamagrostis canadensis*).

Seasonal and semi-permanent marshes with more alkaline water chemistry are commonly found throughout central and eastern Montana. Typical species include hardstem bulrush, cattail, common threesquare (*Schoenoplectus pungens*), alkali bulrush (*Shoenoplectus maritimus*) and inland saltgrass (*Distichlis spicata*), red swampfire (*Salicornia rubra*) and prairie cordgrass (*Spartina pectinata*) in adjacent drawdown zones. These marsh communities are brackish and support species adapted to saline and alkaline water and soil conditions, similar to Western Great Plains Saline Depression systems.

Typically, riverine marshes subjected to unaltered, seasonal water flow and annual flooding are characterized by zonal vegetation determined by water depth with stands of bulrush (*Schoenoplectus* species), softstem bulrush (*Schoenoplectus tabernaemontani*), and cattail in deeper water, and manna grass (*Glyceria* species), water sedge, inflated sedge, water horsetail and common spikerush in shallower water zones. Riverine marshes can be influenced by beaver activity and human caused influences that can change the structure and species richness of these plant communities. Beaver activity can increase species richness and diversify community structure by altering water flow, depth, and organic sediment accumulation.

Dynamic Processes

Wet-drought year climatic cycles in Montana, often in 10 to 20 year cycles, influence the ecological communities in these systems (Hansen et al., 1995). During this climatic cycle, wetlands go through a dry marsh, regenerating marsh, degenerating marsh and a lake phase that is regulated by periodic drought and deluge (Mitsch and Gosselink, 2000). During drought periods, seeds from annuals and perennials germinate and cover exposed mud flats, but when precipitation floods the depressions, the annuals drown and the perennials survive, regenerating the marsh. Over a series of years, perennials dominate and submersed and floating-leaved hydrophytes return. After a few years of the regenerating phase, emergent vegetation begins to decline and eventually the marsh reverts to an open water system. Muskrats may play an important role in the decline of emergent vegetation in some of these systems. During drought, the drawdown to mudflats is necessary so that emergent vegetation can become reestablished. Flooding, drawdown and the eventual exposure of mud flats drive the water-level vegetation cycle. In saline soil marshes, increase in precipitation during exceptionally wet years can dilute the salt concentration in the soils, allowing for less salt-tolerant species to occur.

Species richness can vary considerably among individual examples and is especially influenced by adjacent land use. Agriculture and forestry operations, when adjacent, may cause nutrient and herbicide runoff.

Management
Changes will occur in the plant communities due to climatic conditions and/or management activities. Draining, ditching or conversion to agriculture and pastureland can alter the hydrology of the system. Moderate to Heavy grazing practices can greatly decrease cover of beaked sedge, and cause soil compaction. Invasive and exotic species such as reed canarygrass (*Phalaris arundinacea*), common reed (*Phragmites australis*) and Canadian thistle (*Cirsium arvense*) become established in areas of heavy grazing or other disturbances. Diversion or lateration of seasonal flooding in riverine systems can change the species composition and successional direction of riverine marsh communities.

Restoration Considerations
In marsh systems where water has been drained or altered, the original hydrology of the system must be restored. If water levels are restored, re-growth and re-colonization from dormant rhizomatous root systems of common marsh species can occur within a few years. Cattle grazing must be eliminated or controlled to allow regrowth, recolonization and resprouting from existing root systems. Many of the characteristic species found in marsh systems are rhizomatous, thus exhibit excellent erosion control properties. In some cases, if hydric soils are heavily altered due to pugging or compaction, addition of organic material may be needed to facilitate vegetation recolonization.

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Rocky Mountain Alpine-Montane Wet Meadow

General Description
These moderate-to-high-elevation systems are found throughout the Rocky Mountains, dominated by herbaceous species found on wetter sites with very low-velocity surface and subsurface flows. Occurrences range in elevation from montane to alpine at 1,000 to 3,353 meters (3,280-11,000 feet). This system typically occurs in cold, moist basins, seeps and alluvial terraces of headwater streams or as a narrow strip adjacent to alpine lakes (Hansen et al., 1995). Wet meadows are typically found on flat areas or gentle slopes, but may also occur on sub-irrigated sites with slopes up to 10 percent. In alpine regions, sites are typically small depressions located below late-melting snow patches or on snowbeds. The growing season may only last for one to two months. Soils of this system may be mineral or organic. In either case, soils show typical hydric soil characteristics, including high organic content and/or low chroma and redoximorphic features. This system often occurs as a mosaic of several plant associations, often dominated by graminoids such as tufted hairgrass (*Deschampsia caespitosa*), and a diversity of montane or alpine sedges such as small-head sedge (*Carex illota*), small-winged sedge (*Carex microptera*), black alpine sedge (*Carex nigricans*), Holm's Rocky Mountain sedge (*Carex scopulorum*) short-stalk sedge (*Carex podocarpa*) and Payson's sedge (*Carex paysonis*). Drummond's rush (*Juncus drummondii*), Merten's rush (*Juncus mertensianus*), and high elevation bluegrasses (*Poa arctica* and *Poa alpina*) are often present. Forbs such as arrow-leaf groundsel (*Senecio triangularis*), slender-sepal marsh marigold (*Caltha leptosepala*), and spreading globeflower (*Trollius laxus*) often form high cover in higher elevation meadows. Wet meadows are associated with snowmelt and are usually not subjected to high disturbance events such as flooding.

Diagnostic Characteristics
Woody canopy generally less than 10%, total canopy cover more than 10%; subalpine to montane elevations; in snowmelt basins or adjacent to springs, seeps, streams, or lakes, or in areas with high water table; dominated by herbaceous emergent vegetation; organic layer less than 40 cm deep.

Range
This system is found throughout the Rocky Mountains and Intermountain West regions, ranging in elevation from montane to alpine (1000-3600 m). In Montana, they are most common as high-elevation wetlands in the colder and wetter mountains of the Beartooth-Absaroka range and in northwestern Montana.

Environment
Moisture for these wet meadow community types comes from groundwater, stream discharge, overland flow, overbank flow, and precipitation. Salinity and alkalinity are generally low due to the frequent flushing of moisture through the meadow. Depending on the slope, topography, hydrology, soils and substrate, intermittent, ephemeral, or permanent pools may be present. Standing water may be present during some or all of the growing season, with water tables typically remaining at or near the soil surface. Fluctuations of the water table throughout the growing season are not uncommon, however. On drier sites supporting the less mesic types, the late-season water table may be one meter or more below the surface. Soils typically possess a high proportion of organic matter, but this may vary considerably depending on the frequency and magnitude of alluvial deposition. Organic composition of the soil may include a thin layer near the soil surface. Soils may exhibit gleying and/or mottling throughout the profile.

Vegetation
A variety of plant communities are found within this system in Montana. Composition and zonation of wet meadow plant communities represent the competitive abilities, moisture and nutrient requirements, and stress tolerance of anoxic conditions of individual plant species. Variability of water-table depth and reduced soil conditions, soil pH, and saturation duration, strongly influences the distribution and assemblage of species within a wet meadow. Obligate wetland species occur within a fairly restricted range of water-table depth, whereas many common species such as tufted hairgrass, Baltic rush (*Juncus balticus*) and Kentucky bluegrass (*Poa pratensis*) occur over wide ranges. Overlap in ranges of water-table depth for individual species suggests that small changes in hydrology could potentially result in shifts in dominance by different species, and ultimately replacement or loss of certain species.

Many alpine wet meadows throughout the state are dominated by tufted hairgrass, forming a dense stand of tussocks. The tufted hairgrass Temporarily Flooded Herbaceous Alliance has been found at elevations as high as 10,100 feet, but is much more common at lower elevations where it often occupies low gradient areas and slopes less than 15 percent, facing north to northeast (Cooper et al., 1997). This alliance is thought to be found in relatively undisturbed sites (Hansen et al., 1995), while more disturbed sites are dominated by Kentucky bluegrass (*Poa pratensis*), fowl bluegrass (*Poa palustris*), redtop (*Agrostis stolonifera*) and Baltic rush.

In southwestern Montana, wet meadow communities are dominated by species more characteristic of the Middle Rocky Mountains ecoregion, such as Holm's Rocky Mountain sedge (Cooper et al, 1999). Drier sites, especially those where soils and/or hydrology have been disturbed, may be characterized by Baltic rush and clustered field sedge (*Carex praegracilis*) communities. In the Northern Rocky Mountains, shortstalk sedge or Payson's sedge are dominant (Lesica, 2002), often found on slopes that range from zero to eight percent where the growing season lasts only for one to two months. In these northern occurrences, other common graminoids include small-head sedge, lens sedge (*Carex lenticularis*), smallwing sedge, black alpine sedge, beaked sedge (*Carex utriculata*), Drummond's rush, Merten's rush, arctic bluegrass, and alpine bluegrass. Common forbs include woolly pussytoes (*Antennaria lanata*), spreading globeflower, slender-sepal marsh marigold, arrow-leaf groundsel, elephant's head (*Pedicularis groenlandica*), small flowered anemone (*Anemone parviflora*), alpine bistort (*Polygonum viviparum*), Buek's groundsel (*Packera subnuda*), and Rocky Mountain goldenrod *(Solidago multiradiata*). Sibbaldia (*Sibbaldia procumbens*) often occurs in open areas within the turf or open peat. At more montane elevations, extensive shrubby cinquefoil (*Dasiphora fruticosa*) shrublands are frequently found adjacent to this system.

At montane elevations, zonation of wet meadow complexes is evident with sedges such as inflated sedges (*Carex utriculata* and *C. vesicaria*), wooly sedge (*Carex pellita*), Nebraska sedge (*Carex nebrascensis*) and water sedge (*Carex aquatilis*) occupying the wettest zone of the meadow complex. These sedge-dominated communities are typically surrounded by spikerushes (*Eleocharis spp.),* followed by a zone of grasses and forbs such as Baltic rush, bluejoint reedgrass (*Calamagrostis canadensis*), slimstem reedgrass (*Calamagrostis stricta*), pink elephant's head and water ragwort (*Senecio hydrophilus*).

Dynamic Processes

Communities associated with this ecological system are adapted to soils that may be flooded or saturated throughout the growing season. They may also occur on areas with soils that are only saturated early in the growing season, or intermittently during heavy convective storms in summer. Most appear to be relatively stable types, although in some areas these may be impacted by intensive livestock grazing.

Management

Herbaceous wet meadows that have experienced disturbance like excessive grazing or heavy recreational pressure are often invaded by non-native vegetation and are difficult to restore. Typical successional plants to invade disturbed areas include Nebraska sedge (*Carex nebrascensis*), Baltic rush (*Juncus balticus*), and Kentucky bluegrass (*Poa pratensis*). To minimize disturbance, light to moderate grazing can be restricted to periods when the soil is completely dry and can be timed to occur after the maturation of native seedheads (Hansen et al., 1995). Recreational use should be diverted away from these meadows, and pack stock should be fed certified weed-free or pelletized feed.

Restoration Considerations
Large scale restoration projects within this system are usually mine lands reclamation projects in non-protected areas. Small scale projects may occur in areas of heavy recreational use or areas of past intensive grazing.

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Rocky Mountain Subalpine-Montane Fen

General Description
Fens occur infrequently throughout the Rocky Mountains from Colorado north into Canada. They are confined to specific environments defined by groundwater discharge, soil chemistry, and peat accumulation. This system includes poor fens, rich fens and extremely rich fens. Fens form at low points in the landscape or near slopes where groundwater intercepts the soil surface. Groundwater inflows maintain a fairly constant water level year-round, with water at or near the surface most of the time. Constant high water levels lead to accumulation of organic material, usually greater than 40 centimeters (15 inches) except on sites underlain by limestone bedrock. In addition to peat accumulation and perennially saturated soils, extremely rich and iron fens have distinct soil and water chemistry, with high levels of one or more minerals such as calcium, magnesium, or iron. Fens maintain stream water quality through denitrification and phosphorus absorption. They are among the most floristically diverse of all wetland types, supporting a large number of rare and uncommon bryophytes and vascular plant species, as well as providing habitat for uncommon mammals, mollusks and insects. Fens usually occur as a mosaic of herbaceous and woody plant communities. In herbaceous communities, there are several plant associations dominated by sedges (*Carex* species), spikerushes (*Eleocharis* species), and rushes (*Juncus* species). Bryophyte diversity is generally high and includes sphagnum (*Sphagnum* species). Forb diversity is especially high in extremely rich and iron fens. The woody community is typically composed of willow (*Salix* species) and birch (*Betula nana*) carr shrubland. The surrounding landscape may be ringed with other wetland systems: fens often grade into marshes, wet meadows or riparian shrublands, and can be surrounded by conifer swamps or wet to mesic coniferous

forests. In very rare cases, fens can occur within prairie grasslands in the glaciated Great Plains. Fens are found in scattered locations along the Rocky Mountain Front, in the Rocky Mountains and intermountain valleys, in the small isolated central mountain ranges, and at higher elevations on the Beartooth Plateau in the southern portion of the state.

Diagnostic Characteristics

Seepage-fed slopes, montane to subalpine elevations, organic peat layer greater than 40 cm deep, extreme (mineral) rich and iron-rich, saturated soils, bryophytes, graminoids

Range

This system occurs infrequently throughout the Rocky Mountains from Colorado north into Canada. In Montana, small fens are found in scattered locations in the glaciated plains and in the small isolated mountain ranges of the central part of the state. The Swan, Stillwater and Flathead valleys have numerous rich and extremely rich fen systems due to the prevalence of limestone bedrock in the Whitefish, Mission, and Swan mountain ranges. Similarly, rich and extremely rich fens are found along the limestone-rich Front Range east of the Continental Divide. East of the Continental Divide, both small and large rich and extremely rich prairie fens occur on the extreme western Great Plains bordering the Rocky Mountain Front (Lesica, 1986) and rarely, within the northwestern mixed grass prairie (Heidel et al, 2000). Further south in western Montana, poor fen systems are more common in the Bitterroot, Lolo, and Beaverhead ranges, and are found in the granitic, isolated central Montana island ranges and the Beartooth Plateau in southwestern Montana.

Environment

The montane-subalpine fen ecological system is a small-patch system composed of mountain wetlands that support a unique communities of plants not found in other types of wetlands. Fens are confined to specific environments defined by groundwater discharge, soil chemistry, and peat accumulation of at least 40 centimeters (15 inches), although peat accumulations in areas overlain by gravel, cobble or bedrock may be less. Soils are typically organic histosols with 40 centimeters or more of organic material if overlying a mineral soil, or less if overlying bedrock, cobbles or gravels. Histosols range in texture from clayey-skeletal to loamy-skeletal and fine-loams. Fens form at low points in the landscape or near slopes where groundwater intercepts the soil surface. Groundwater inflows maintain a fairly constant water level year-round, with water at or near the surface most of the time. Constant high water levels lead to accumulations of organic material. Rich and extremely rich fens are found in areas underlain by limestone. Water chemistry ranges from only slightly acidic to alkaline and is usually distinctly calcareous. Marl deposits (precipitated calcium carbonates) are common in these systems. Tufa deposits or terraces can be seen in some rich fens and are composed of virtually pure calcium carbonate at the soil surface, formed by continuous discharge and evaporation of calcite saturated groundwater. In northwestern Montana, pH values usually range from 5.9 to 8.4 (Chadde et al., 1998). Poor fens are more common in the northern Rocky Mountains and occur in areas overlain by non-calcareous bedrock, e.g., argillites and granite. These are usually flat, acidic, and saturated to the surface, sometimes with standing water. Iron rich fens are more rare in occurrence, and can be strongly acidic (as low as pH 2.98) and associated with geothermal features and bedrock of weathering pyrite, as found in some occurrences in the Yellowstone Plateau (Lemly, 2007). Iron

rich fens support a diverse bryophyte community, typically have less vascular plant diversity, and are composed of species dependant on more acidic conditions.

Fens develop successionally through lake-filling, flow-through successional processes or by paludification (Chadde et al., 1998). Lake filling occurs in depressions and is often characterized by the presence of floating mats and a ring of carr vegetation on the outer margin of the peatland. Flow-through fens are the most common in the northern Rocky Mountains. They occur along springs, streams, slopes and benches with a constant inflow and outflow of calcium-rich water. They are characterized by a series of linear hummocks oriented perpendicular to the slope. Carr shrubland is well developed in flow-through fens due to well-aerated, nutrient-rich water near the inflow and outflow zones. Usually there is an open, nutrient- poor community in the central portion of the fen. Paludification occurs when fens expand due to a rise in the water table caused by peat accumulation. This process is most often observed near seeps and springs or adjacent to closed basin peatlands where peat accumulation causes wetter conditions along the outer edges. Higher water tables kill existing trees. In the northern Rocky Mountains, this successional process is limited due to prolonged summer droughts; however it may be seen in some fen systems at higher elevations.

In northwestern Montana, fens occur at montane to subalpine elevations, generally ranging from 985-2,165 meters (2,500-5,500 feet). In southwestern Montana, subalpine and alpine fens occur at higher elevations (Heidel and Rodemaker, 2008). These communities typically occur in seeps and wet sub-irrigated meadows in narrow to broad valley bottoms. Surface topography is typically smooth to concave with lake-fill peatlands or with slopes ranging from 0 to 10 percent in flow-through fens.

Vegetation
Floristically, rich and extremely rich fens support the greatest vascular plant species diversity of all peatland types in the Rocky Mountains. Extremely rich fens are characterized by high species diversity and a mosaic of herbaceous and woody plant communities. In contrast, poor fens have scattered vascular plant cover and lower species diversity but are characterized by a nearly continuous and diverse cover of mosses and other bryophytes.

Several vascular plants have been identified as extremely rich or rich fen indicators in Montana, and some of these species are uncommon or rare. Indicators include: sage-leaf willow (*Salix candida*), simple bog sedge (*Kobresia simpliciuscula*), Bellardii bog sedge (*Kobresia myosuroides*), Rolland's small clubrush (*Trichophorum pumilum*), little green sedge (*Carex viridula*), northern single spike sedge (*Carex scirpoidea*), pale sedge (*Carex livida*), bulblet-bearing water hemlock (*Cicuta bulbifera*), slender cottongrass (*Eriophorum gracile*), green keeled cottongrass (*Eriophorum viridicarinatum*), beaked spikerush (*Eleocharis rostellata*), northern bog violet (*Viola nephrophylla*), pale bog laurel (*Kalmia polifolia*), Kalm's lobelia (*Lobelia kalmii*), and yellow widelip orchid (*Liparis loeselii*). Other orchids such as giant helleborine orchid (*Epipactis gigantea*) are found in open sedge-dominated portions of the fen system, while one-leaf orchid (*Ameorchis rotundifolia*), sparrow's egg ladyslipper (*Cypripedium passerinum*) and small yellow ladyslipper (*Cypripedium parviflorum*) occur on raised sphagnum hummocks around trees and shrubs near the perimeter of the fen. These species are found almost

exclusively in fens or wet forest habitats bordering fens. Poor fens often include species found in more acidic conditions such as pale bog laurel (*Kalmia polifolia*), rannoch rush (*Scheuchzeria palustris*) and sundews (*Drosera* species).

In extremely rich and rich fens, the herbaceous community is often dominated by beaked sedges (*Carex utriculata* or *Carex rostrata*), water sedge (*Carex aquatilis*), mud sedge (*Carex limosa*), woolyfruit sedge (*Carex lasiocarpa*), spikerush (*Eleocharis species*), cottongrass (*Eriophorum species*), rushes (*Scirpus* species and *Trichophorum* species) and bulrushes (*Shoenoplectus* species). Other frequent species include Buxbaum's sedge (*Carex buxbaumii*), analogue sedge (*Carex simulata*), northern bog sedge (*Carex gynocrates*), bristly-stalked sedge (*Carex leptalea*), poor sedge (*Carex paupercula*), yellow sedge (*Carex flava*), hair sedge (*Carex capillaris*), silvery sedge (*Carex canescens*), lens sedge (*Carex lenticularis*), Baltic rush (*Juncus balticus*), northern rush (*Juncus alpino-articulatus*), dagger leaf rush (*Juncus ensifolius*), threadleaf rush (*Juncus filiformis*), common spike rush (*Eleocharis palustris*), and few-flowered spike rush (*Eleocharis quinqueflora*). Common grasses include bluejoint reedgrass (*Calamagrostis canadensis*), tufted hairgrass (*Deschampsia cespitosa*), and fringed brome (*Bromus ciliatus*).

Rich and extremely rich fens also support high forb diversity. Common species include showy pussytoes (*Antennaria pulcherrima*), bog orchid (*Plantanthera* species), buckbean (*Menyanthes trifoliata*), elegant death camas (*Zigadenus elegans*), grass-of-parnassus (*Parnassia* species), beautiful shooting-star (*Dodecatheon pulcherrinum*), pink elephant's head (*Pedicularis groenlandica*), arrow-grass (*Triglochin palustris*), and Siberian chives (*Allium schoenoprasum*). At subalpine elevations, common butterwort (*Pinguicula vulgaris*) often occurs near seeps or springs, in areas where there is marl accumulation or on tufa deposits or terraces.

In Montana, wet, floating *Sphagnum*-dominated mats are associated with open water edges or depressional areas of fen systems. Bryophyte floating mats often consist of Meesia moss (*Meesia triquetra*), Scorpidium moss (*Scorpidium* species), Magellan's peatmoss (*Sphagnum magellanicum*) and brown peatmoss (*Sphagnum fuscum*). The bryophyte floating mat supports a very minor component of sedges such as mud sedge (*Carex limosa*) and smaller sedges such as grape sedge (*Carex aurea*), softleaf sedge (*Carex disperma*) and inland sedge (*Carex interior*), as well as cottongrass species (*Eriophorum* species). Fen indicators such as pale laurel (*Kalmia polifolia*), rannoch rush (*Scheuchzeria palustris*) and sundews (*Drosera* species) occur on these floating mats. Buckbean (*Menyanthes trifoliata*) is a late seral species from the sedge mat phase and is often present on floating mats.

Fens are frequently bordered by willow-bog birch (*Salix* species-*Betula nana glandulosa*) dominated carrs. Carr shrubland is well developed in flow-through fens due to highly-aerated nutrient-rich water near the inflow and outflow zones or the perimeter of basin fens. Sageleaf willow (*Salix candida*) is an indicator species, and sometimes the dominant willow species. Other willow species include autumn willow (*Salix serrissima*), Bebb's willow (*Salix bebbiana*), Drummond's willow (*Salix drummondiana*), plane-leaf willow (*Salix planifolia*), wolf willow (*Salix wolfii*), and undergreen willow (*Salix commutata*). Other common carr shrubs include alder (*Alnus* species), bog birch (*Betula nana*), alder buckthorn (*Rhamnus alnifolia*), shrubby cinquefoil (*Dasiphora fruticosa*), and western Labrador tea (*Ledum glandulosum*). Engelmann

spruce (*Picea engelmannii*) is the most frequent conifer species associated with fens and forested fen margins of these systems (Hansen and others, 1995).

Dynamic Processes
Mountain fens act as natural filters, cleaning ground and surface water. Fens also act as sponges by absorbing heavy precipitation, then slowly releasing it downstream, minimizing erosion and recharging groundwater systems. Persistent groundwater and cold temperatures allow organic matter to accumulate, forming peat, which allows classification of wetlands within this system as fens. Peat accumulates at the rate of 8 to 11 inches per 1000 years, making peatlands a repository of 10,000 years of post-glacial history.

Management
Land uses surrounding fens can potentially alter the hydrology and nutrient inputs of these systems, thus changing their underlying processes. Increased land use within 100 meters has been found to be correlated with increased nutrient levels in peatlands in Montana, suggesting that setbacks should be 100 meters or more for adequate protection (Jones 2003). Draining, heavy cattle use, and irrigation practices can also alter hydrology and result in the loss of species diversity. Localized peat mining may occur on private lands.

Restoration Considerations
The degree of damage that has occurred in a fen has a significant impact on the prospects for restoration. Peat mining will cause irreversible damage to fen systems because Rocky Mountain fens build peat so slowly (8 to 11 inches per 1,000 years). In fen systems where water has been drained or altered, the original hydrology of the system must be restored before any vegetation restoration can be considered. If water levels are restored, re-growth and re-colonization of peat mosses can occur, although this is a very slow process. In deeper waters, regeneration depends on whether residual peat layers will become buoyant. Regeneration largely depends on water chemistry and residual peat layer quality. When peat quality is inadequate, shallow inundation is recommended (Smolders et al., 2002).

Heavy cattle use in a fen system can alter the hydrology by damaging soils within the fen system. Soil compaction and pugging within the peat layer will change surface water flow. Heavy cattle use can also alter the successional processes within the sedge- dominated area of a fen. Cattle hoof action can lead to pugging and hummocking, creating microsites where shrubs can become established, changing the sedge-dominated meadow to carr shrubland.

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Appendix B. Montana Natural Heritage Program Wetland Assessment Forms

ASSESSMENT AREA INFORMATION	
Site ID	Date
Site Name	Observer(s)
Level 4 Ecoregion	
Land Ownership	
HUC4/HUC5/HUC6	
GPS Coordinates at the assessment area center (UTMs)	Notes on movement of the AA center:
Waypoint ID	
Datum	
Easting (X)	
Northing (Y)	
Accuracy Elevation	
General AA description, including surrounding uplands	
Directions to AA and Access Comments:	

Soil Drainage (check one)		Topographic Position (check one)		Amount of AA Covered by Standing Water (check one)	
Well-drained		slope		none	
Mod well-drained		depression		1-25%	
Poorly drained		floodplain		26-50%	
Very poorly drained		flat		51-75%	
				76-100%	

Assessment Area Photos-Taken from the center of the AA in the four cardinal directions		
Photo #	Photo Card	Description
Photo #	N	
Photo #	E	
Photo #	S	
Photo #	W	
Additional Photos:		

CLASSIFICATION

Ecological System (check one--use Key to Ecological Systems)

____RM Fen
____RM Wet Meadow
____W. N. Am. Emergent Marsh
____RM Riparian Shrubland
____RM Riparian Woodland
____NRM Wooded Vernal Pool
____LM Riparian Woodland and Shrubland
____Other

Confidence Level
_____Very High
_____High
_____Medium
_____Low

Dominant Vegetation Association(s)

Reason for selecting confidence level:

HGM Class (check one)
_____Riverine
_____Depressional
_____Flat
_____Lacustrine Fringe
_____Slope

Confidence Level
_____Very High
_____High
_____Medium
_____Low

Reason for selecting confidence level:

Cowardin System
_____Palustrine (P)
_____Lacustrine Littoral (L2)
_____Riverine Lower Perennial (R2)
_____Riverine Upper Perennial (R3)

Cowardin Class
_____Aquatic Bed (AB)
_____Moss Lichen (ML)
_____Emergent (EM)
_____Forested (FO)
_____Scrub-Shrub (SS)
_____Unconsolidated Bottom (UB)
_____Unconsolidated Shore (US)

Cowardin Water Regime
_____Permanently Flooded (H)
_____Intermittently Exposed (G)
_____Semi-permanently Flooded (F)
_____Artificially Flooded (K)
_____Seasonally Flooded (C)
_____Saturated (B)
_____Temporarily Flooded (A)
_____Intermittently Flooded (J)

Cowardin Special Modifers
_____Beaver (b)
_____Farmed (f)
_____Excavated (x)
_____Partially ditched/drained (d)
_____Diked/impounded (h)

ASSESSMENT AREA DRAWING (add north arrow, document plant zones, indicate direction of drainage into or out of wetland, and include sketch of vegetation plot and soil pit placement). ALSO INDICATE ALL PLANT ZONES ON AERIAL PHOTO, IF POSSIBLE

Notes:

SOIL PROFILE DATA FORM

SiteID ______________

Soil Pit # __________ **GPS Waypoint Easting** __________________ (draw soil pit location on site drawing) **Northing** ______________ **Accuracy** ______________

Depth (cm)	Layer	Texture	Matrix Color* (Hue/Value/Chroma)	Redox Concentrations (Hue/Value/Chroma)	Redox Depletions (Hue/Value/Chroma)	Redox Concentration Abundance (%)	Redox Depletion Abundance (%)	**Hydric Soil Indicators Present? (Yes/No)	Depth to Saturation (cm)	Depth to free water in pit (cm) (NP=not present)

TOTAL PIT DEPTH (cm) ______

****Hydric Soil Indicators (check all that apply):**

__________ Histosol (Organic layer greater than 20 cm)
__________ Histic Epipedon (Organic layer at least 20 cm from surface)
__________ Sulfidic (rotten eggs) odor
__________ Organic streaking (dark vertical streaks in the subsurface layers)
__________ Gleyed or Low Chroma Colors
__________ Redox depletions-areas in soil that have lost iron; gray or reddish-gray in color
__________ Redox concentrations-oxidation of iron; in patches, along root channels and in pores

Note: Redoximorphic features cannot form in soils with parent materials that are low in iron and manganese

Remarks:

*To determine the soil matrix color: if soils are dry, wet sample until it no longer changes color. Always have the sun at your back when comparing to color chart to find best match.

SOIL PROFILE DATA FORM

SiteID _______________

Soil Pit # __________ **GPS Waypoint Easting** __________________ (draw soil pit location on site drawing) **Northing** ______________ **Accuracy** ______________

Depth (cm)	Layer	Texture	Matrix Color* (Hue/Value/Chroma)	Redox Concentrations (Hue/Value/Chroma)	Redox Depletions (Hue/Value/Chroma)	Redox Concentration Abundance (%)	Redox Depletion Abundance (%)	**Hydric Soil Indicators Present? (Yes/No)	Depth to Saturation (cm)	Depth to free water in pit (cm) (NP=not present)

TOTAL PIT DEPTH (cm) ______

****Hydric Soil Indicators (check all that apply):**

__________ Histosol (Organic layer greater than 20 cm)
__________ Histic Epipedon (Organic layer at least 20 cm from surface)
__________ Sulfidic (rotten eggs) odor
__________ Organic streaking (dark vertical streaks in the subsurface layers)
__________ Gleyed or Low Chroma Colors
__________ Redox depletions-areas in soil that have lost iron; gray or reddish-gray in color
__________ Redox concentrations-oxidation of iron; in patches, along root channels and in pores

Note: Redoximorphic features cannot form in soils with parent materials that are low in iron and manganese

Remarks:

*To determine the soil matrix color: if soils are dry, wet sample until it no longer changes color. Always have the sun at your back when comparing to color chart to find best match.

Plant Zones in Entire Assessment Area						
Height Scale for Each Plant Zone				Cover Scale for Each Plant Zone		
1	<0.5 m	6	10-15 m	1	Trace	6	10-<25%
2	0.5-1 m	7	15-20 m	2	<1%	7	25-<50%
3	1-2 m	8	20-35 m	3	1-<2%	8	50-<75%
4	2-5 m	9	35-50 m	4	2-<5%	9	75-<95%
5	5-10 m	10	>50 m	5	5-<10%	10	>95%

Identify and describe the plant zones that occur within the assessment area. A plant zone should be described if it meets the following rules: **1a**. The plant zone is dominated by a stratum distinctly different from the stratum that dominates other plant zones; OR **1b**. the plant zone is dominated by the same stratum as other plant zones, BUT each plant zone is dominated by different species AND the average height of the dominant species differs by > 1 m (e.g., *Typha latifolia* vs. *Juncus balticus*). **2**. The plant zone makes up more than 5% of the AA (e.g., 250 m^2 for an AA of 0.5 ha). **3**. Each individual patch of the plant zone is greater than $10m^2$.

Plant Zone #1 (indicate location on site drawing)

Stratum	Leaf Type (can check more than one)		
_____Forest/Woodland (Trees/Shrubs > 5 m)	_____Broad-leaved	_____Needle-leaved	
_____Shrubland (Shrubs >0.5-5 m)	_____Broad-leaved	_____Needle-leaved	_____Microphyllous
_____Dwarf Shrubland (<0.5 m)	_____Broad-leaved	_____Needle-leaved	_____Microphyllous
_____Herbaceous (e.g., Graminoids, Forbs, Ferns)	_____Graminoid	_____Forb	_____Fern
_____Nonvascular (Bryophytes, cryptogamic crusts)			
_____Submerged/Floating (Rooted or floating-exclude emergent)			
_____Sparsely Vegetated (including bare ground)			

Dominant Species	Height Class	Cover Class	Comments

Stratum #2 (indicate location on site drawing)

Stratum	Leaf Type (can check more than one)		
_____Forest/Woodland (Trees/Shrubs > 5 m)	_____Broad-leaved	_____Needle-leaved	
_____Shrubland (Shrubs >0.5-5 m)	_____Broad-leaved	_____Needle-leaved	_____Microphyllous
_____Dwarf Shrubland (<0.5 m)	_____Broad-leaved	_____Needle-leaved	_____Microphyllous
_____Herbaceous (e.g., Graminoids, Forbs, Ferns)	_____Graminoid	_____Forb	_____Fern
_____Nonvascular (Bryophytes, cryptogamic crusts)			
_____Submerged/Floating (Rooted or floating-exclude emergent)			
_____Sparsely Vegetated (including bare ground)			

Dominant Species	Height Class	Cover Class	Comments

Stratum #3 (indicate location on site drawing)			
Stratum ______Forest/Woodland (Trees/Shrubs > 5 m) ______Shrubland (Shrubs >0.5-5 m) ______Dwarf Shrubland (<0.5 m) ______Herbaceous (e.g., Graminoids, Forbs, Ferns) ______Nonvascular (Bryophytes, cryptogamic crusts) ______Submerged/Floating (Rooted or floating-exclude emergent) ______Sparsely Vegetated (including bare ground)			Leaf Type (can check more than one) ______Broad-leaved ______Needle-leaved ______Broad-leaved ______Needle-leaved ______Microphyllous ______Broad-leaved ______Needle-leaved ______Microphyllous ______Graminoid ______Forb ______Fern
Dominant Species	Height Class	Cover Class	Comments

Stratum #4 (indicate location on site drawing)			
Stratum ______Forest/Woodland (Trees/Shrubs > 5 m) ______Shrubland (Shrubs >0.5-5 m) ______Dwarf Shrubland (<0.5 m) ______Herbaceous (e.g., Graminoids, Forbs, Ferns) ______Nonvascular (Bryophytes, cryptogamic crusts) ______Submerged/Floating (Rooted or floating-exclude emergent) ______Sparsely Vegetated (including bare ground)			Leaf Type (can check more than one) ______Broad-leaved ______Needle-leaved ______Broad-leaved ______Needle-leaved ______Microphyllous ______Broad-leaved ______Needle-leaved ______Microphyllous ______Graminoid ______Forb ______Fern
Dominant Species	Height Class	Cover Class	Comments

Stratum #5 (indicate location on site drawing)			
Stratum ______Forest/Woodland (Trees/Shrubs > 5 m) ______Shrubland (Shrubs >0.5-5 m) ______Dwarf Shrubland (<0.5 m) ______Herbaceous (e.g., Graminoids, Forbs, Ferns) ______Nonvascular (Bryophytes, cryptogamic crusts) ______Submerged/Floating (Rooted or floating-exclude emergent) ______Sparsely Vegetated (including bare ground)			Leaf Type (can check more than one) ______Broad-leaved ______Needle-leaved ______Broad-leaved ______Needle-leaved ______Microphyllous ______Broad-leaved ______Needle-leaved ______Microphyllous ______Graminoid ______Forb ______Fern
Dominant Species	Height Class	Cover Class	Comments

LANDSCAPE CONTEXT		
Connectivity		
Non-riverine	Select the statement that best describes the **landscape connectivity** within a 500 m buffer of the AA: **1**. Intact: AA embedded in 90-100% unfragmented, natural landscape. **2**. Variegated: AA embedded in 60-90% unfragmented, natural landscape. **3**. Fragmented: AA embedded in 20-60% unfragmented, natural landscape. **4**. Relictual: AA embedded in <20 % unfragmented, natural landscape.	
Riverine	Select the statement that best describes the **landscape connectivity** within 500 m upstream and downstream of the AA: **1**. Intact: AA embedded in 90-100% unfragmented, natural landscape. **2**. Variegated: AA embedded in 60 90% unfragmented, natural landscape. **3**. Fragmented: AA embedded in 20-60% unfragmented, natural landscape. **4**. Relictual: AA embedded in <20 % unfragmented, natural landscape.	
Buffer		
Length	Select the statement that best describes the **buffer length** of the AA: **1**. Buffer is 76-100% of the AA perimeter. **2**. Buffer is 51-75% of the AA perimeter. **3**. Buffer is 25-50% of the AA perimeter. **4**. Buffer is <25% of the AA perimeter, OR no buffer exists.	
Width	Select the statement that best describes the **buffer width** of the AA: **1**. Average buffer width between edge of the AA and the edge of the buffer is >200 m. **2**. Average buffer width between edge of AA and the edge of the buffer is >100-200 m. **3**. Average buffer width between edge of the AA and the edge of the buffer is 50-100 m. **4**. Average buffer width between edge of the AA and the edge of the buffer is <50 m, OR no buffer exists.	
Condition	Select the statement that best describes the **buffer condition** of the AA: **1**. Abundant (>95%) native vegetation cover, little or no (<5%) cover of non-native plants, intact soils, AND little or no trash. **2**. Substantial (>75–95%) native vegetation cover, low (5–25%) cover of non-native plants, intact or moderately disturbed soils, moderate or lesser amounts of trash, OR evidence of minor human visitation or recreation. **3**. Moderate (50-75%) native vegetation cover, moderate or extensive soil disturbance, moderate or greater amounts of trash, OR evidence of moderate human visitation or recreation. **4**. Low (<50%) cover of native vegetation, barren ground and highly disturbed soils, moderate or greater amounts of trash, evidence of high intensity human visitation or recreation, OR no buffer exists.	
Buffer Condition Comments	Describe elements that are NOT considered part of the buffer (e.g., roads, agriculture, etc.)	
SIZE		
Relative Patch Size	Select the statement that best describes the **relative patch size** of the entire wetland (current size of the wetland divided by the historic size of the wetland): **1**. Wetland is >95% of original size. **2**. Wetland is >80-95% of original size. **3**. Wetland is >50-80% of original size. **4**. Wetland is <50% of original size.	
Absolute Patch Size	Estimate the size of the entire wetland (from the aerial photo OR from the GIS). IF YOU ARE UNABLE TO ESTIMATE SIZE, PLEASE INDICATE ON THE FORM THAT THE SIZE SHOULD BE ESTIMATED IN THE OFFICE.	
VEGETATION STRUCTURE (BIOTA)		
Relative Cover of Native Plant Species	Select the statement that best describes the **relative cover of native plant species** within the AA: **1**. >99% of the vegetation cover within the AA is comprised of native vegetation. **2**. 95-99% of the vegetation cover within the AA is comprised of native vegetation. **3**. 80-94% of the vegetation cover within the AA is comprised of native vegetation. **4**. <80% of the vegetation cover within the AA is comprised of native vegetation. **5**. <50% of the vegetation cover within the AA is comprised of native vegetation.	
Invasive exotic species	Select the statement that best describes **invasive exotic species** within the AA: **1**. <1% of the vegetation cover within the AA is comprised of invasive exotic species. **2**. 1-3% of the vegetation cover within the AA is comprised of invasive exotic species. **3**. >3-5% of the vegetation cover within the AA is comprised of invasive exotic species. **4**. >5% of the vegetation cover within the AA is comprised of invasive exotic species.	
Invasive or highly tolerant natives	Select the statement that best describes the **invasive or highly tolerant natives** within the AA: **1**. <5% of the vegetation cover within the AA is comprised of invasive or tolerant native plant species. **2**. 5-10% of the vegetation cover within the AA is comprised of invasive or tolerant native plant species. **3**. >10-25% of the vegetation cover within the AA is comprised of invasive or tolerant native plant species. **4**. >25% of the vegetation cover within the AA is comprised of invasive or tolerant native plant species.	

Organic Matter Accumulation	Select the statement that best describes the **organic matter accumulation** of the site: **1.** Site has moderate amount of fine organic matter. New growth is more prevalent than previous years' growth. Layers of litter in pools or areas of topographic lows are thin. **2.** Site is characterized by small amounts of coarse organic debris, with little plant recruitment, OR debris is somewhat excessive. **3.** Site has little coarse debris and/or only scant fine debris OR debris is excessive.	
Physical Patch Types	How many **physical patch types** occur within the site (refer to physical patch type table)?	
Patch Interspersion	Select the statement that best describes the **patch interspersion** of the site: **1**. Horizontal structure consists of a very complex array of nested or interspersed irregular biotic/abiotic patches with no single dominant type. **2**. Horizontal structure consists of a moderately complex array of nested or interspersed irregular biotic/abiotic patches with no single dominant type. **3**.Horizontal structure consists of a simple array of nested or interspersed irregular biotic/abiotic patches with no single dominant type. **4**. Horizontal structure consists of one dominant patch type with no interspersion.	
PHYSICOCHEMICAL		
Soil Surface Integrity	Select the statement that describes the **soil surface integrity** of the site: **1**. Bare soil is limited to naturally caused disturbances such as flood deposition or game trails. **2**. Some bare soil due to human causes (including livestock) is present but the extent and impact is minimal. The depth of disturbance is limited to only a few inches and does not show evidence of ponding or channeling water. Any disturbance is likely to recover within a few years after the disturbance is removed. **3**. Bare soil due to human causes is common and will be slow to recover. There may be pugging due to livestock resulting in several inches of soil disturbance. ORVs or other machinery may have left some shallow ruts. Damage is not excessive and the site will recover with the removal of degrading human influences and moderate recovery times. **4**. Bare soil substantially degrades the site due to altered hydrology or other long-lasting impacts. Deep ruts from ORVs or machinery may be present, or livestock pugging and/or trails are widespread. Water, if present, would be channeled or ponded. The site will not recover without restoration and/or long recovery times.	
Water Quality	Select the statement that best describes the **water quality** of the site: **1.** No visual evidence of degraded water quality. Wetland species that respond to high nutrient levels are minimally present, if at all. Water is clear with no strong green tint or sheen. **2.** Some negative water quality indicators are present, but limited to small and localized areas within the wetland. Wetland species that respond to high nutrient levels may be present but are not dominant. Water may have a minimal greenish tint, cloudiness, or sheen. **3.** Negative water quality indicators or wetland species that respond to high nutrient levels are common. Sources of water quality degradation are apparent. Water may have a moderate greenish tint, sheen or other turbidity with algae common. **4.** Wetland is dominated by vegetation species that respond to high nutrient levels or there is widespread evidence of other negative water quality indicators. Algal mats may be extensive, blocking light to the bottom. Sources of water quality degradation are typically apparent. Water has strong greenish tint, sheen, or turbidity. The bottom difficult to see during the growing season.	
HYDROLOGY		
Water Source	Select the statement that best describes the **water source under dry season conditions of the AA**: **1.** Sources are precipitation, groundwater, and/or natural runoff, or natural flow from an adjacent freshwater body, or the AA naturally lacks water in the dry season. 2. Sources are mostly natural but can include occasional or small effects of modified hydrology (e.g., developed land or irrigated agricultural land comprising less than 20% of the drainage basin within 2 km of the AA, presence of a few small stormdrains or scattered homes with septic systems). No large point sources or dams control the overall hydrology. **3**. Sources or withdrawals are primarily from anthropogenic sources (e.g., urban runoff, direct irrigation, diversions, pumped water, impoundments, regulated releases through a dam, developed or irrigated agricultural land comprising more than 20% of the drainage basin within 2 km of the AA, presence of major drainage point source discharges that obviously control the hydrology of the AA). **4**. Natural sources have been eliminated based on the following indicators: impoundment of all wet season inflows, diversions of all dry-season inflows, predominance of xeric vegetation, etc.	
Hydroperiod (for depressional, lacustrine, and slope wetlands--NOT fens)	Which of the following statements best describes the **hydroperiod** of the site: **1**. Hydroperiod of the AA is characterized by natural patterns of filling or inundation and drying or drawdowns. **2**. The filling or inundation patterns in the AA are of greater magnitude or duration than would be expected under natural conditions, but thereafter the AA is subject to natural drawdown or drying. **3**. Hydroperiod of the AA is characterized by natural patterns of filling or inundation, but thereafter, is subject to more rapid or extreme drawdown or drying, as compared to more natural wetlands. OR The filling or inundation patterns in the AA are of substantially lower magnitude or duration than would be expected under natural conditions, but thereafter, the AA is subject to natural drawdown or drying. **4**. Both the inundation and drawdown of the AA deviate from natural conditions (either increased or decreased in magnitude and/or duration).	

Hydroperiod (for fens)	Select the statement that best describes the **hydroperiod** of the site: **1**. Hydroperiod of the site is characterized by stable, saturated hydrology, or by naturally damped cycles of saturation and partial drying. **2**. Hydroperiod of the site experiences minor altered inflows or drawdown/drying, as compared to more natural wetlands (e.g., ditching). **3**. Hydroperiod of the site is somewhat altered by greater increased inflow from runoff, or experiences moderate drawdown or drying, as compared to more natural wetlands (e.g., ditching). **4**. Hydroperiod of the site is greatly altered by increased inflow from runoff or experiences large drawdown or drying, as compared to more natural wetlands (e.g., ditching).	
Hydroperiod (for riverine sites)	Select the statement that best describes the **hydroperiod** of the site (based on field indicators in the worksheet): **1**. Most of the channel through the AA is characterized by equilibrium conditions, with little evidence of aggradation or degradation. **2**. Most of the channel through the AA is characterized by some aggradation or degradation, none of which is severe, and the channel seems to be approaching an equilibrium form. **3**. There is evidence of severe aggradation or degradation of most of the channel through the AA, or the channel is artificially hardened through less than half of the AA. **4**. The channel is concrete or otherwise artificially hardened through most of the AA.	
Groundwater Connectivity	Are there areas within the assessment area buffer that indicate groundwater connectivity (e.g., visually confirmed, temporary surface water connection to an upslope wetland; areas of vigorous growth of upland vegetation relative to the surrounding uplands).	
Hydrologic Connectivity (for depressional, lacustrine, and slope wetlands--NOT isolated fens)	Select the statement that best describes the **hydrologic connectivity** of the site: **1**. Rising water in the AA has unrestricted access to adjacent areas without levees or other obstructions to the lateral movement of flood waters. **2**. Unnatural features such as levees or road grades limit the amount of adjacent transition zone or the lateral movement of floodwaters, relative to what is expected for the setting, but the limitations exist for less than 50% of the AA perimeter. Restrictions may be intermittent along the margins of the AA, or they may occur only along one bank or shore. **3**. The amount of adjacent transition zone or the lateral movement of flood waters to and from the AA is limited, relative to what is expected for the setting, by unnatural features such as levees or road grades, for 50–90% of the AA perimeter. Flood flows may exceed the obstructions, but drainage out of the AA is probably obstructed. **4**. The amount of adjacent transition zone or the lateral movement of flood waters is limited, relative to what is expected for the setting, by unnatural features such as levees or road grades, for more than 90% of the AA perimeter.	
Hydrologic Connectivity (for naturally isolated fens)	Select the statement that best describes the **hydrologic connectivity** of the site: **1**. No natural connectivity with the surrounding water bodies. **2**. Partial connectivity (e.g., ditching or draining to dry the fen). **3**. Substantial to full connectivity that has obvious effects of drying the peat body.	
Hydrologic Connectivity (for confined riverine wetlands)	Select the statement that best describes the **hydrologic connectivity** of the site based on the entrenchment ratio calculation: **1**. Entrenchment ratio >2.0. **2**. Entrenchment ratio 1.6-2.0. **3**. Entrenchment ratio 1.2-1.5. **4**. Entrenchment ratio <1.2.	
Hydrologic Connectivity (for unconfined riverine wetlands)	Select the statement that best describes the **hydrologic connectivity** of the site based on the entrenchment ratio calculation: **1**. Entrenchment ratio >2.2. **2**. Entrenchment ratio 1.9-2.2. **3**. Entrenchment ratio 1.5-1.8. **4**. Entrenchment ratio <1.5.	

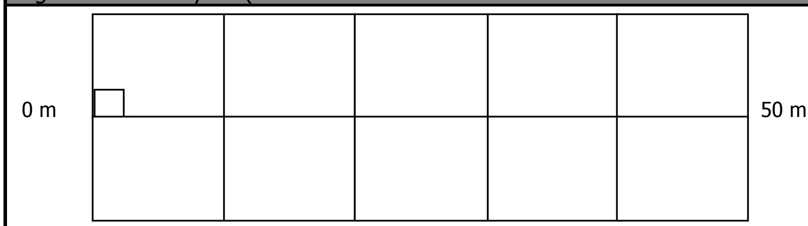
PHYSICAL PATCH TYPE	CHECK ONE
Open water-pond or lake	
Open water -pools	
Open water-river/stream	
Open water-oxbow/backwater channel	
Open water-tributary/secondary channel	
Open water-beaver pond	
Deep emergent plants (> 0.5 m water depth)	
Shallow emergent plants (< 0.5 m water depth)	
Submerged/floating vegetation	
Active beaver dam	
Adjacent or onsite springs/seeps	
Shrubs/Trees	
Transitional meadow	
Saline meadow	
Debris jams/woody debris	
Pool/riffle complex	
Point bars	
Mudflats	
Wet meadow patches	
Plant hummocks/sediment mounds	
Water tracks/hollows	
Tall herbaceous vegetation (> 0.5 m tall)	
Low herbaceous vegetation (< 0.5 m tall)	
Floating mat	
Vegetation cover dominated by sedges/moss	
Number of observed patches	

Land Use Observed Within 500 m of the AA	Check all that apply
Paved roads / parking lots	
Domestic or commercially developed buildings	
Gravel pit operation, open pit mining, strip mining	
Unpaved Roads (e.g., driveway, tractor trail, 4-wheel drive roads)	
Mining (other than gravel, open pit, and strip mining), abandoned mines	
Resource extraction (oil and gas development)	
Agriculture - dryland farming	
Intensively managed golf courses, sports fields	
Vegetation conversion (chaining, cabling, rotochopping, clearcut)	
Heavy grazing by livestock	
Intense recreation (ATV use / camping / popular fishing spot, etc.)	
Logging or tree removal with 50-75% of trees >50 cm dbh removed	
Agriculture – irrigated cropland	
Agriculture – permanent tree plantation	
Dam sites and flood disturbed shorelines around water storage reservoirs	
Recent old fields and other disturbed fallow lands dominated by exotic species	
Moderate grazing on rangeland	
Moderate recreation (high-use trail)	
Selective logging or tree removal with <50% of trees >50 cm dbh removed	
Light grazing on rangeland	
Light recreation (low-use trail)	
Haying of native grassland	
Fallow with no history of grazing or other human use in past 10 yrs	
Natural area / land managed for native vegetation	
Land Use Observed Within the AA	
Vegetation conversion (chaining, cabling, rotochopping, clearcut)	
Heavy grazing by livestock	
Intense recreation (ATV use / camping / popular fishing spot, etc.)	
Logging or tree removal with 50-75% of trees >50 cm dbh removed	
Dam sites and flood disturbed shorelines around water storage reservoirs	
Recent old fields and other disturbed fallow lands dominated by exotic species	
Moderate grazing	
Moderate recreation (high-use trail)	
Selective logging or tree removal with <50% of trees >50 cm dbh removed	
Light grazing	
Light recreation (low-use trail)	
Natural area / land managed for native vegetation	
Hydrology Within 500 m of the AA	
Upstream spring boxes	
Impoundment	
Pumps, diversions, or ditches that move water out of the wetland	
Evidence of aquatic life mortality	
Encroachment of terrestrial vegetation	
Stress or mortality of hydrophytes	
Compressed or reduced plant zonation	
Berm	
Dike	
Pumps, diversions, or ditches that move water into the wetland	
Recently drowned riparian vegetation	
Extensive fine-grained deposits	

SiteID	________________				
0 m					
GPS Waypoint	________________	(draw vegetation plot location on site drawing)			
Easting	________________	Northing	________________	Accuracy	________________
50 m					
GPS Waypoint	________________	(draw vegetation plot location on site drawing)			
Easting	________________	Northing	________________	Accuracy	________________

Vegetation Plot Photos	**Module**	**Bearing/Description**
Photo #		
Photo #		
Photo #		
Photo #		
Photo #		

Vegetation Plot Layout (circle the location of the intensive modules and note any changes to the plot layout)



Notes:

Plot Representativeness (discuss decisions for placement and/or whether the plot is representative of the assessment area)

Plant species presence and percent cover: For each intensive module, starting with the uppermost stratum, list all species in each stratum and estimate percent cover for the module. For tree species, estimate seedling, sapling, and mature trees separately. List any species found in the remaining modules in the residual "R" column and estimate percent cover for the entire plot. List any species outside the plot at the end of the table or designate with a 0 in Cover Class column. Mark location of the intensive modules on aerial photo for reference.

Cover Scale for Strata			
1	Trace	6	10-<25%
2	<1%	7	25-<50%
3	1-<2%	8	50-<75%
4	2-<5%	9	75-<95%
5	5-<10%	10	>95%

VEGETATION PLOT SPECIES TABLE

		Module	**1**		**2**	**3**	**4**	**5**	**R**
		Cover Class	**Corner**	**Module**					
Stratum		**Species**							
Water									
Bare Ground									
Litter									
Bryophytes (all cover, including under vegetation or litter cover)									

Appendix C. Montana NHP Rapid Assessment Scoring Procedure

For each metric, convert narrative rating score (1, 2, 3, and 4) into the corresponding metric score: 1=12, 2=9, 3=6, and 4=3.

Each final attribute score was calculated according to the following:

Landscape Context (LC) Attribute Score:

Raw score = [Buffer Condition x (Buffer width x Buffer length)$^{1/2}$]$^{1/2}$ + Landscape Connectivity

$$\text{Final Attribute score} = \frac{\text{Raw Landscape Context Score}}{\text{Total possible points allowed (24)}} \times 100$$

Relative Patch Size Attribute Score:

$$\text{Final Attribute score} = \frac{\text{Relative Patch Size Score}}{\text{Total possible points allowed (12)}} \times 100$$

Biotic Attribute Score:

$$\text{Raw score} = \frac{\text{(Invasive native + Native + Invasive scores)}}{3} + \text{Organic Matter accumulation} + \text{patch interspersion}$$

$$\text{Final Attribute Score} = \frac{\text{Raw Biotic Score}}{\text{Total possible points allowed (36)}} \times 100$$

Hydrology Attribute Score:

Raw score = Hydrological Source + Hydroperiod + Hydrologic Connectivity scores

$$\text{Final Attribute Score} = \frac{\text{Raw Hydrology Score}}{\text{Total possible points allowed (36)}} \times 100$$

Physicochemical Attribute Score:

Raw score = Soil Surface Integrity + Water Quality scores

$$\text{Final Attribute Score} = \frac{\text{Raw Physicochemical Score}}{\text{Total possible points allowed (24)}} \times 100$$

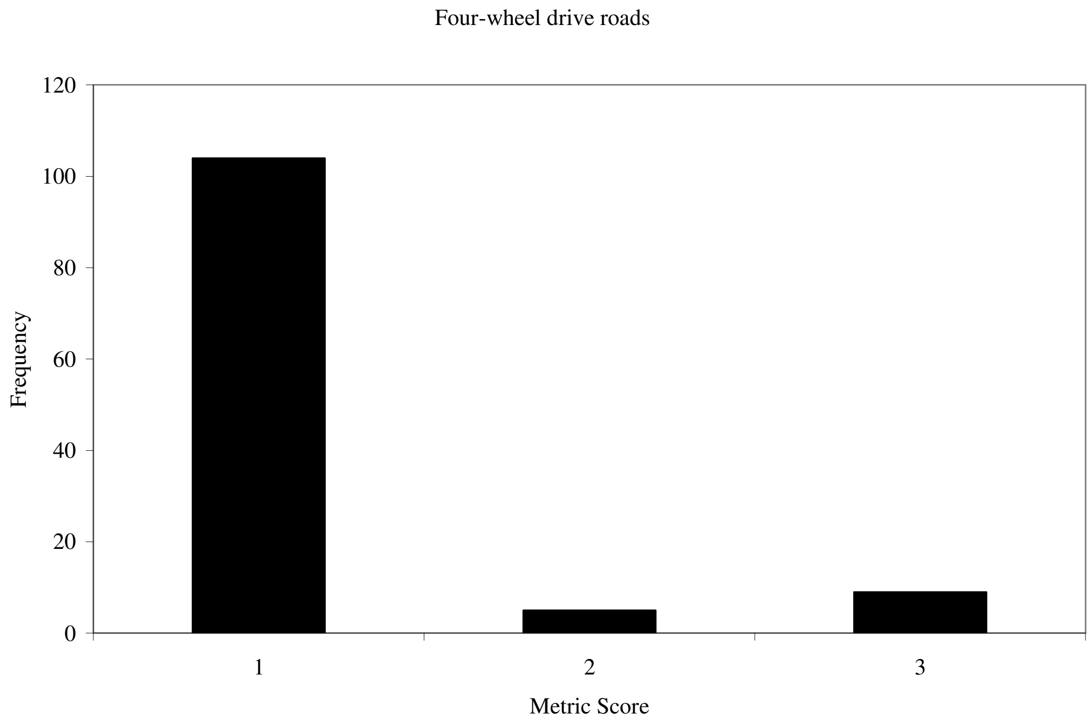
$$\text{Final AA Score} = \frac{\text{Final LC + Final Patch Size + Final Biotic + Final Hydro +Final Physicochemical score}}{5}$$

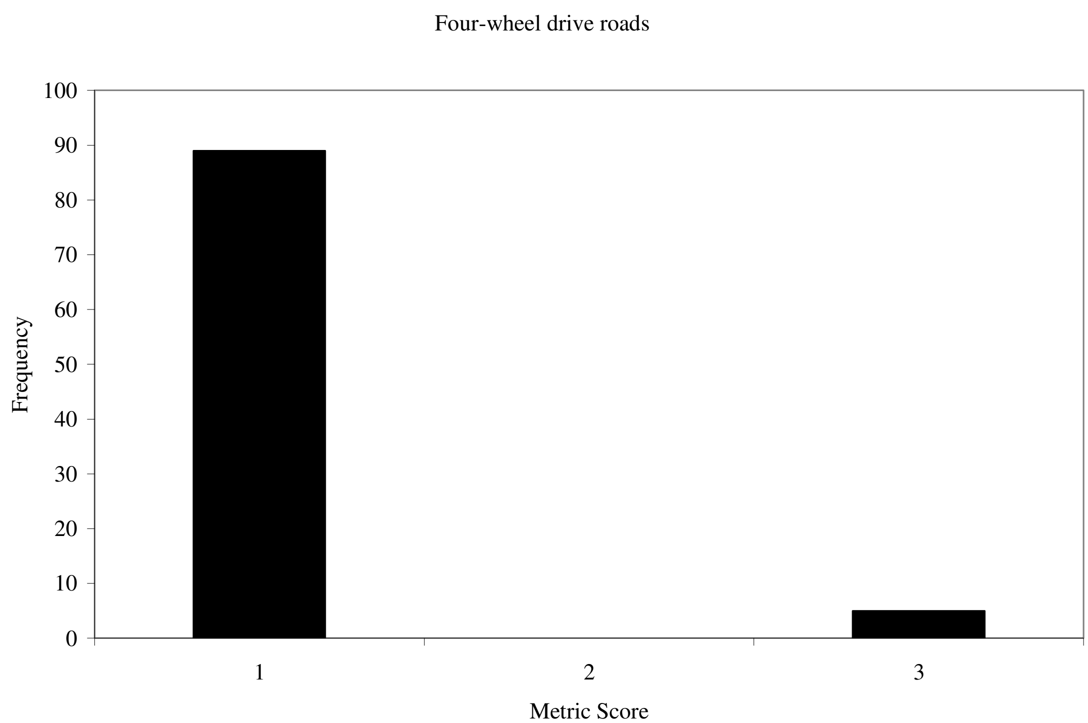
APPENDIX D. VEGETATION METRIC CALCULATIONS

Indices	Formulas
Number of all species	$N + A$
Number of native species	N
Number of exotic species	A
Mean C-value of all species	$\bar{C} = \sum_{j=1}^{N+A} C_i \Big/ N + A$
Mean C-value of native species	$\bar{C} = \sum_{j=1}^{N} C_i \Big/ N$
Cover weighted mean C-value of all species	$\bar{C} = \sum_{j=1}^{N+A} p_i C_i \Big/ N + A$
Cover weighted mean C-value of native species	$\bar{C} = \sum_{j=1}^{N} p_i C_i \Big/ N$
Floristic Quality Index of native species	$FQI = \bar{C}\sqrt{N}$
Floristic Quality Index for all species	$FQIall = \bar{C}\sqrt{N + A}$
Cover weighted FQI of native species	$\text{CWFQInat} = \left(\sum_{j=1}^{N} p_j C_j\right)\sqrt{N}$
Cover weighted FQI of all species	$\text{CWFQI} = \left(\sum_{j=1}^{N+A} p_j C_j\right)\sqrt{N + A}$
Adjusted FQI of all species	$adjFQI = \left(\bar{C} \big/ 10\right)\left(\sqrt{N} \big/ \sqrt{N + A}\right) * 100$
Cover weighted adjusted FQI of all species	$adjCWFQI = \left(CW\overline{Cnat} \big/ 10\right)\left(\sqrt{N} \big/ \sqrt{N + A}\right) * 100$

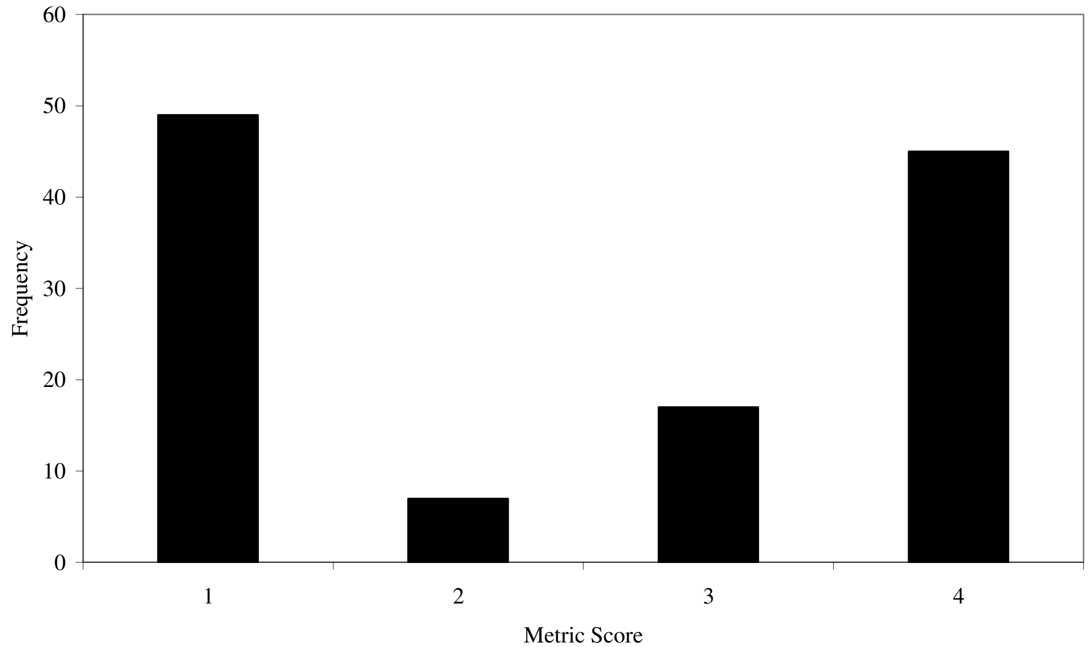
Appendix E. Level 1 Metric Frequency Histograms

Northwestern Great Plains and Northwestern Glaciated Plains wetlands are on top; Middle Rockies, Northern Rockies, and Canadian Rockies wetlands are on the bottom.

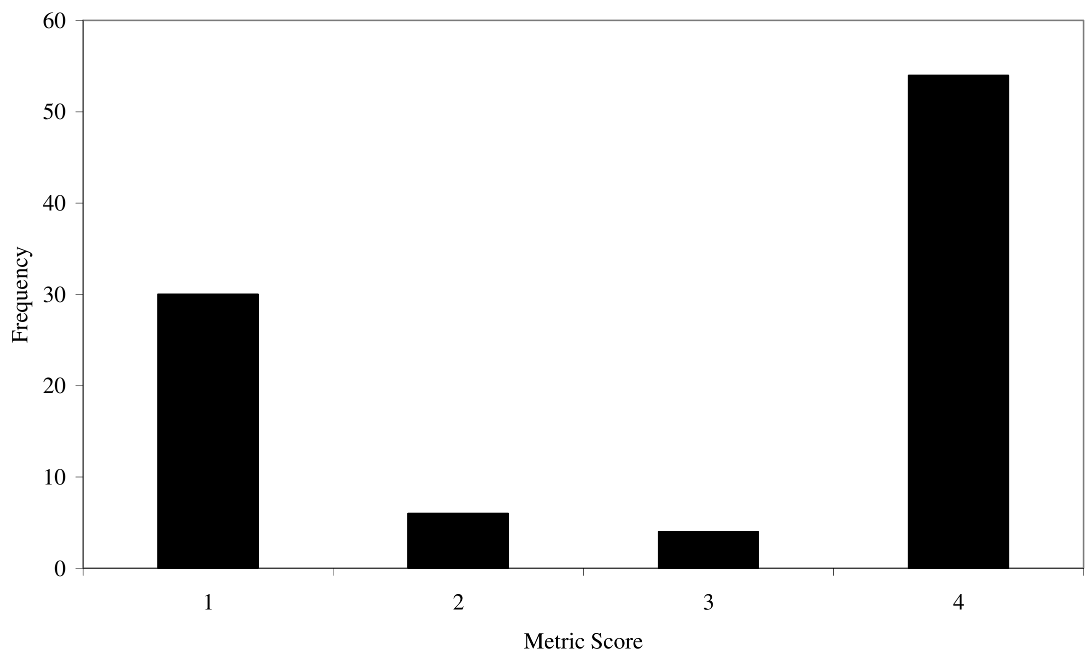


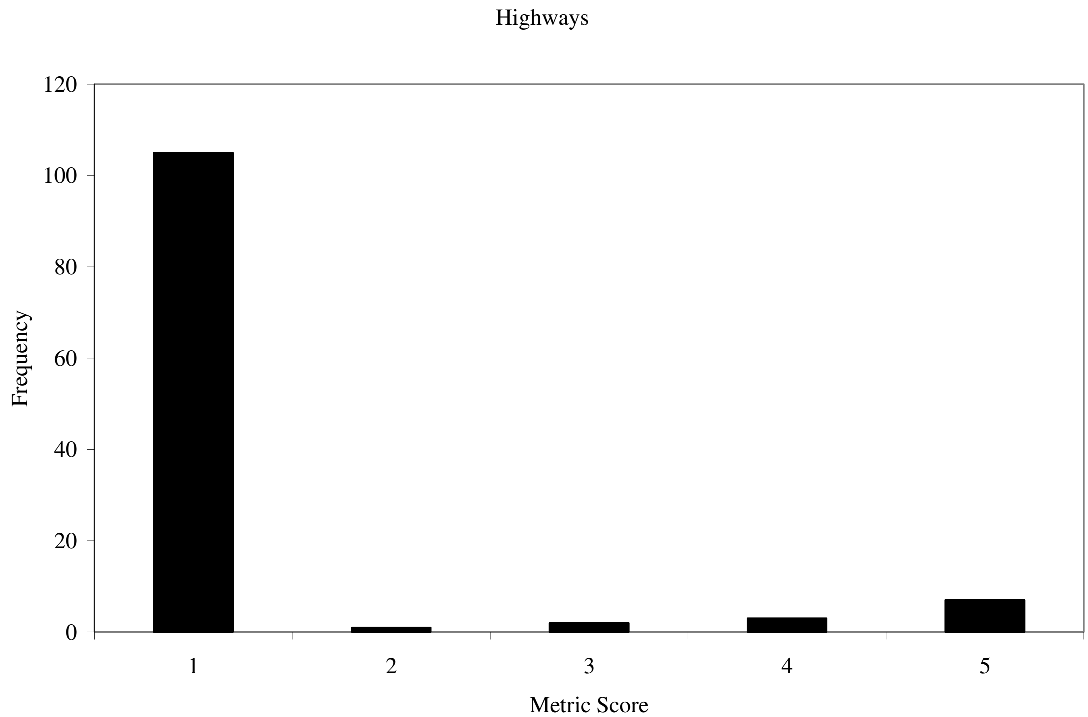


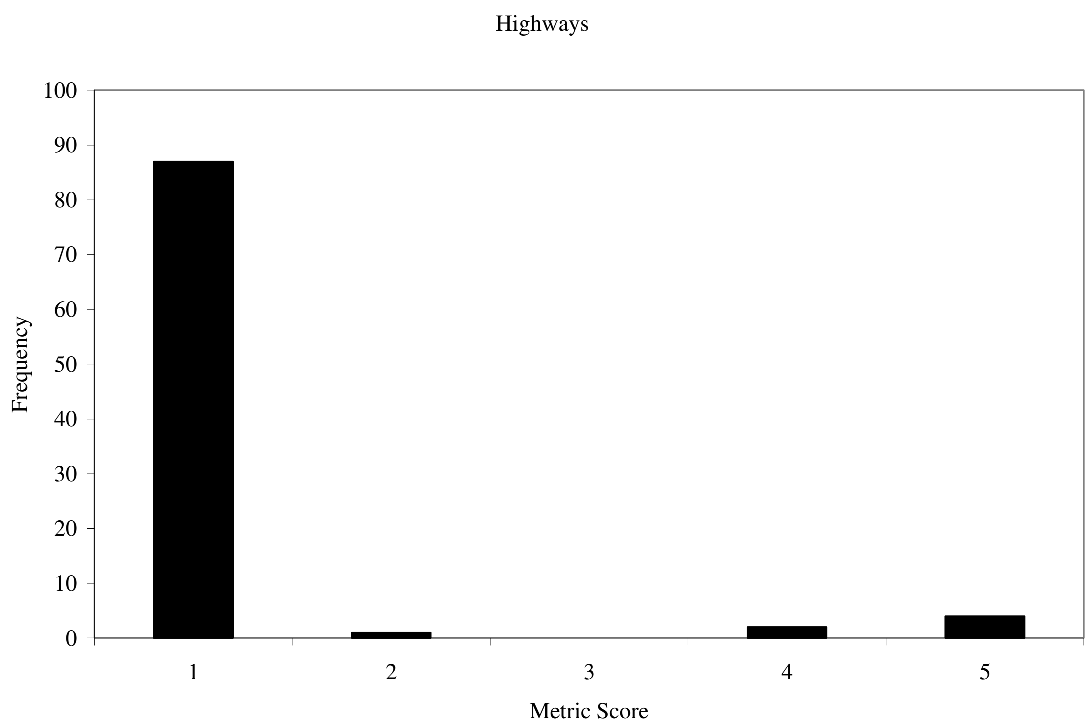
Local and secondary roads



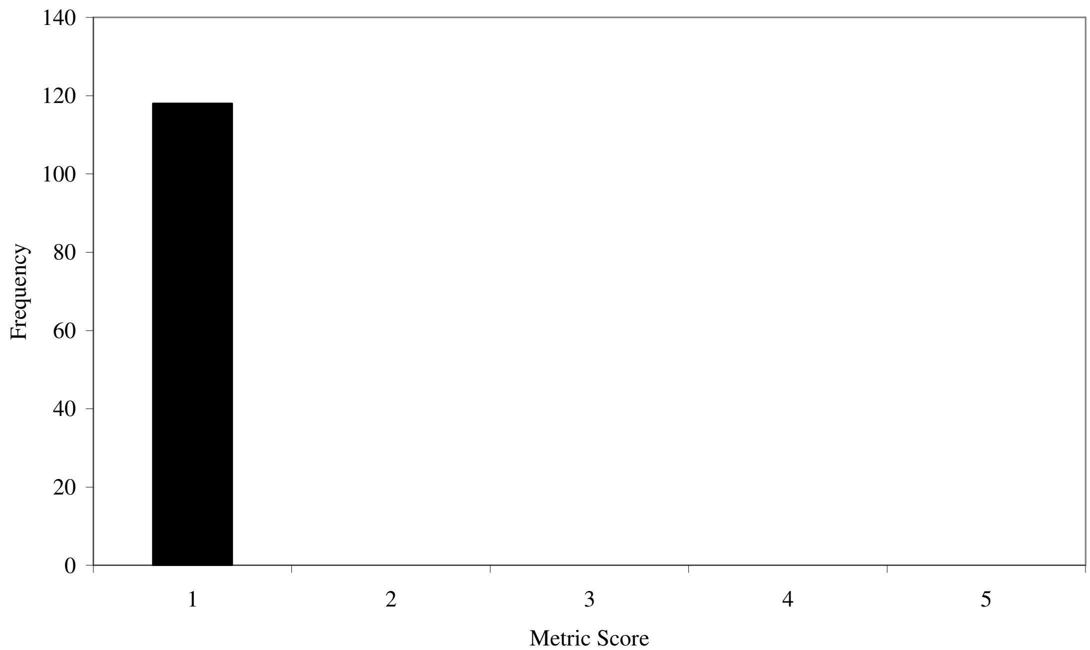
Local and secondary roads



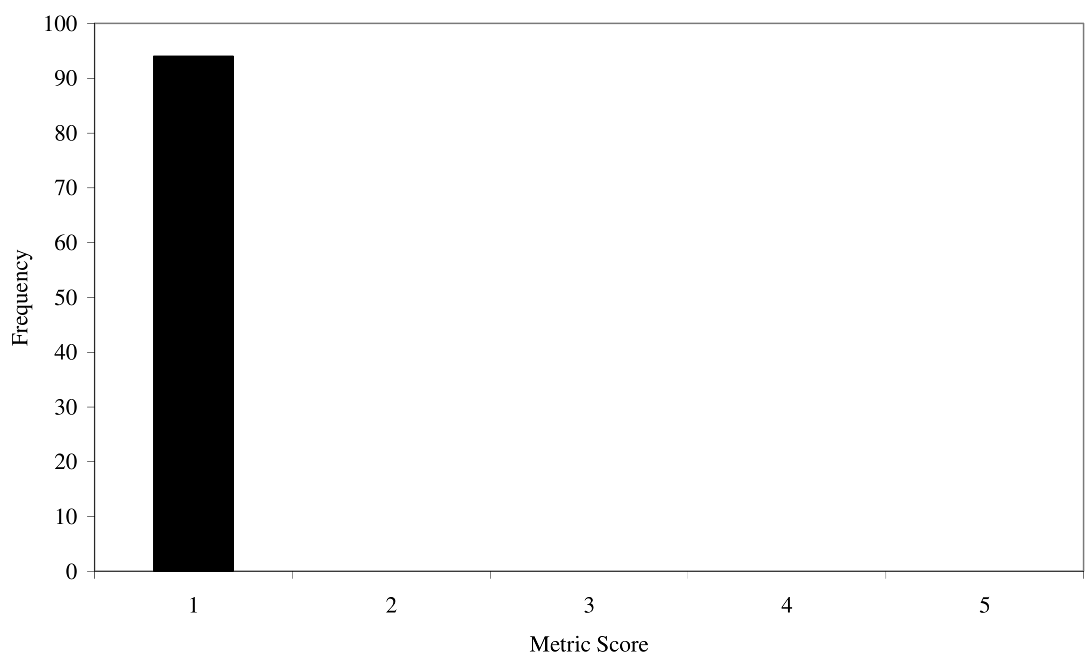

Highways
Frequency
120
100
80
60
40
20
0
1
2
3
4
5
Metric Score


Highways
Frequency
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Metric Score

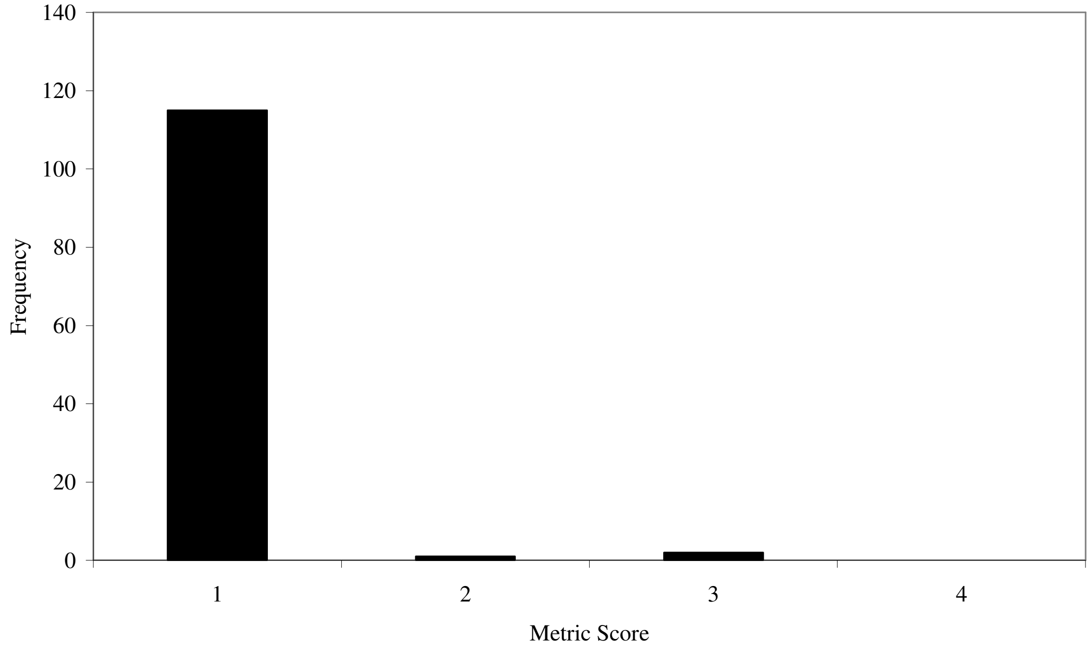
Medium density development



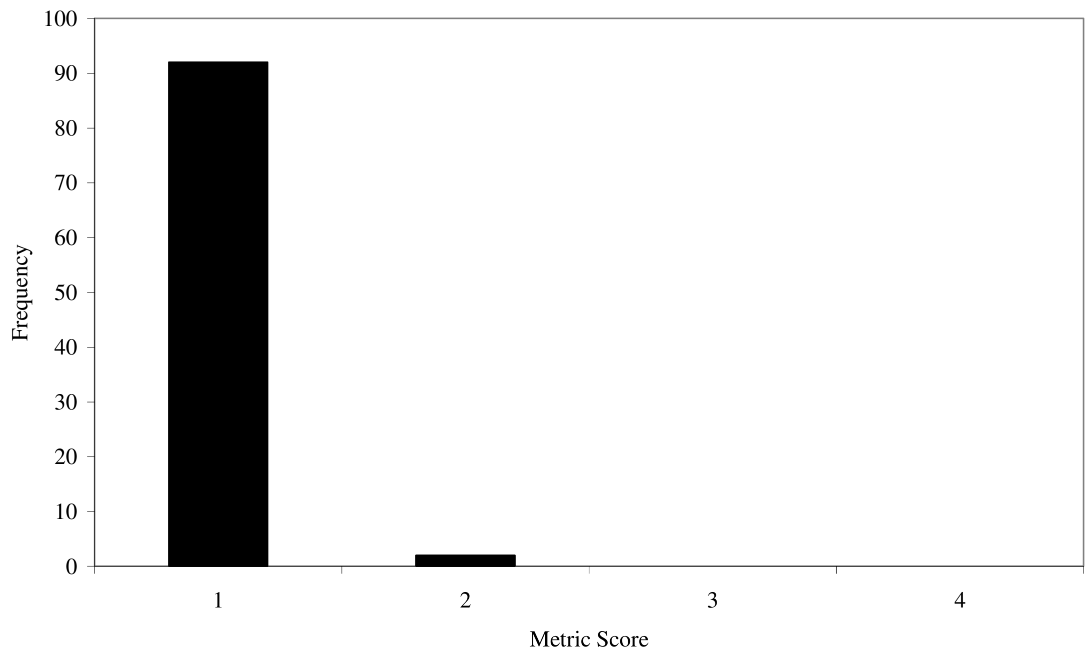
Medium density development



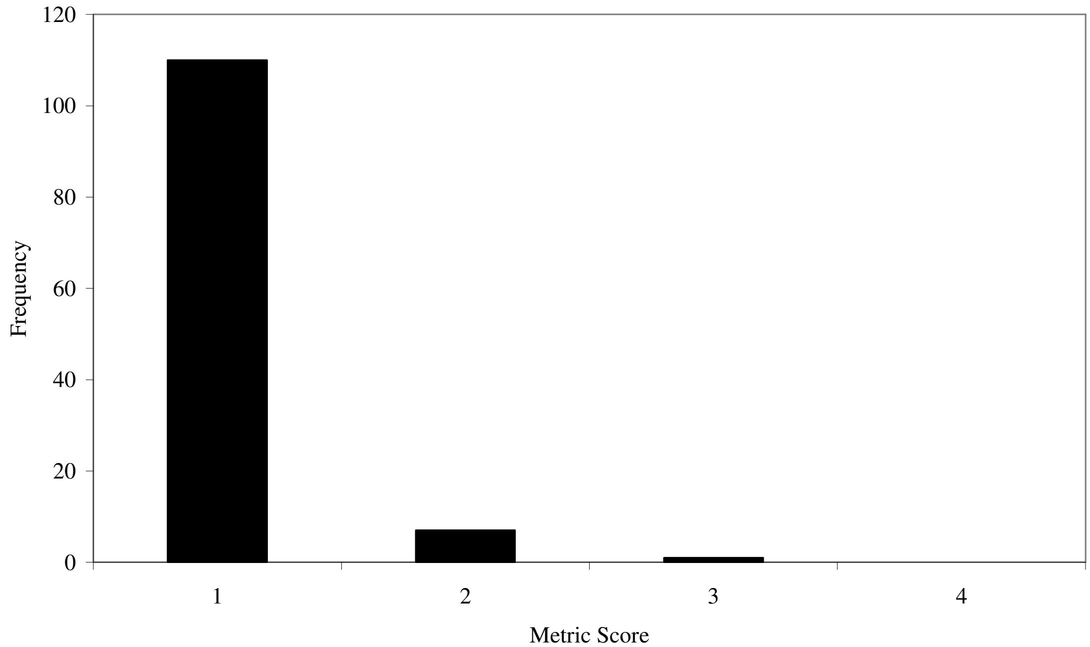
Low density development



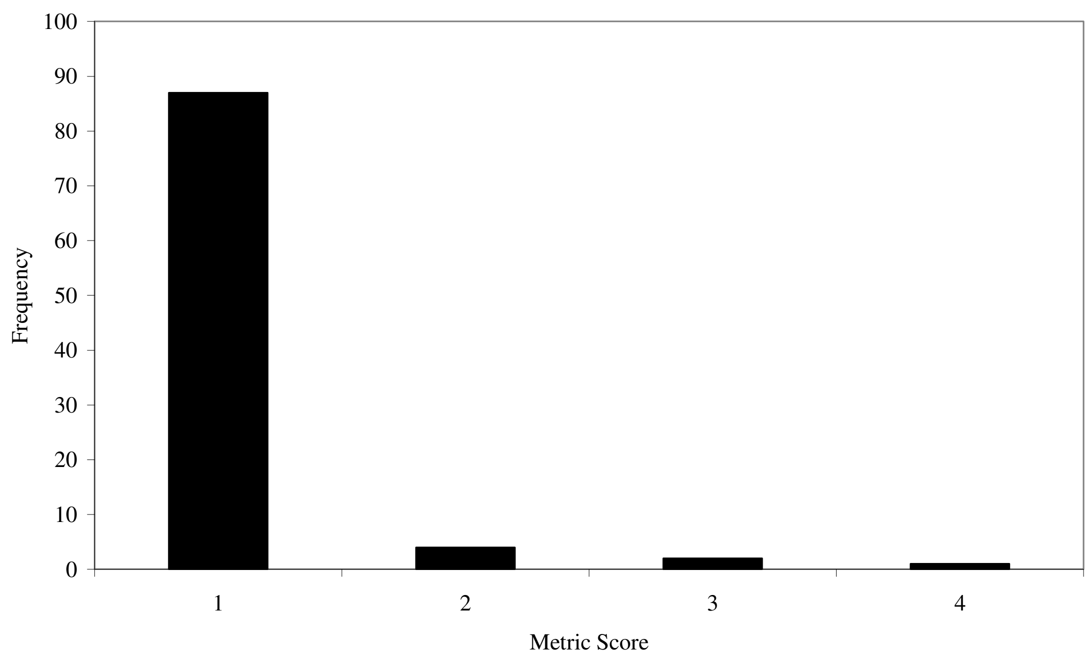
Low density development

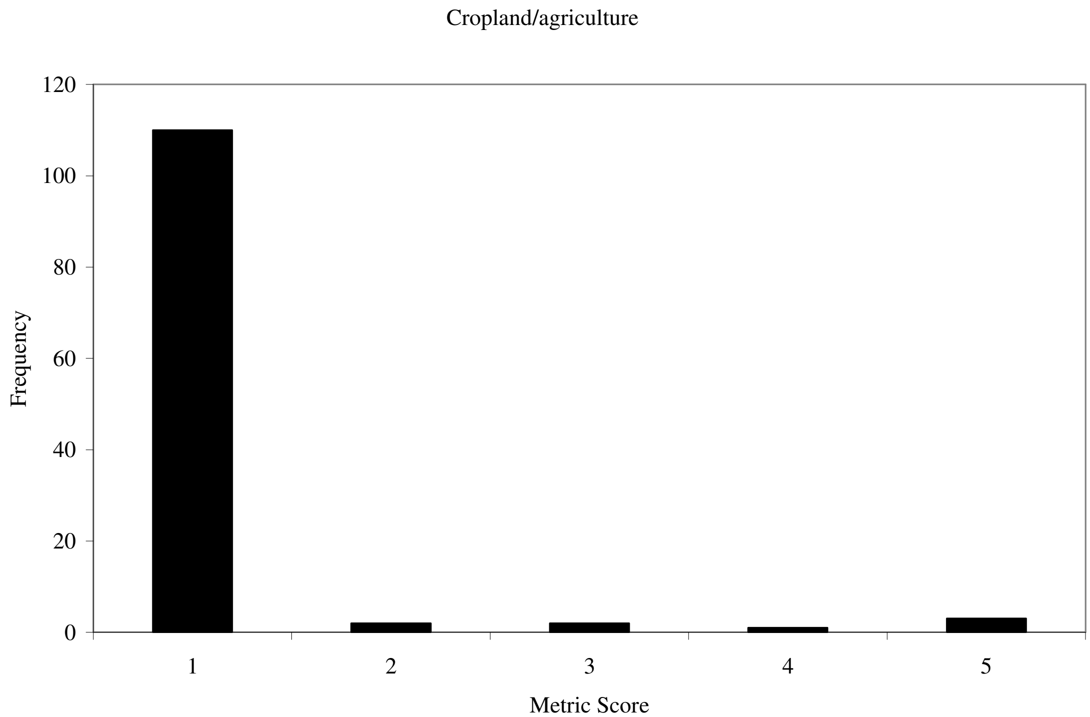


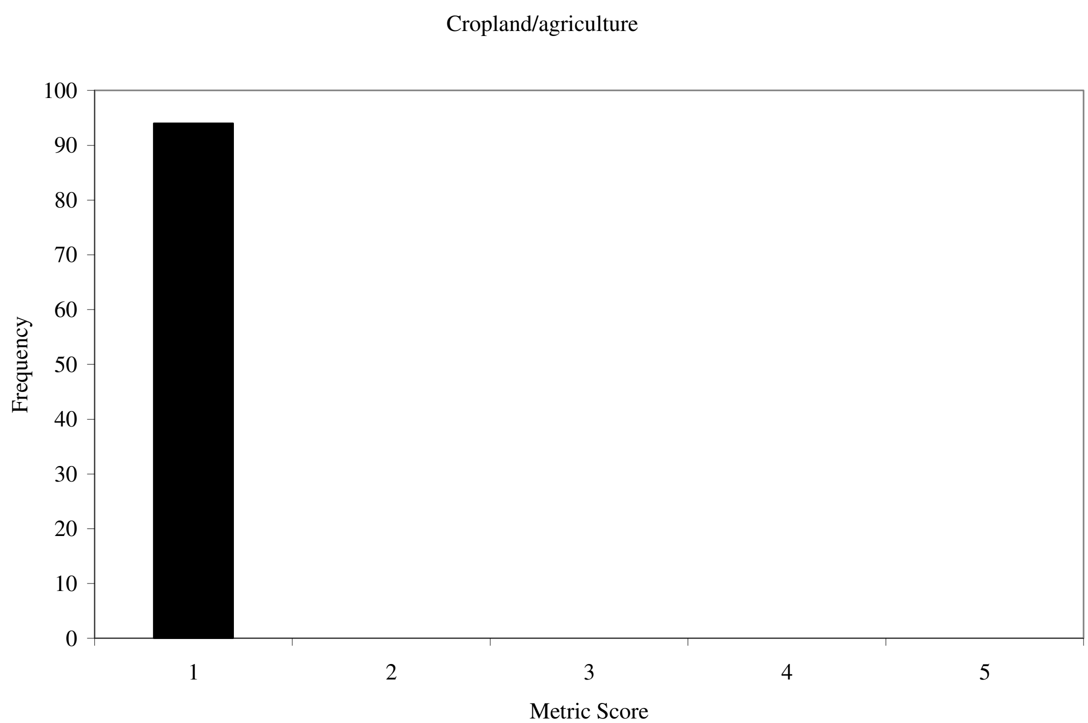
Developed open space



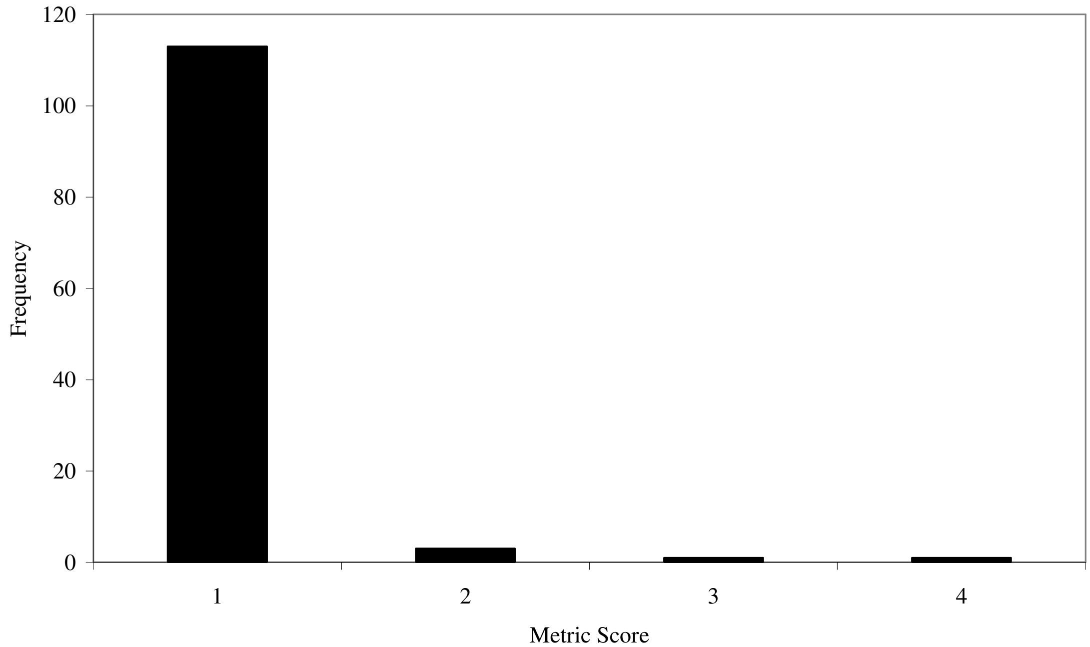
Developed open space



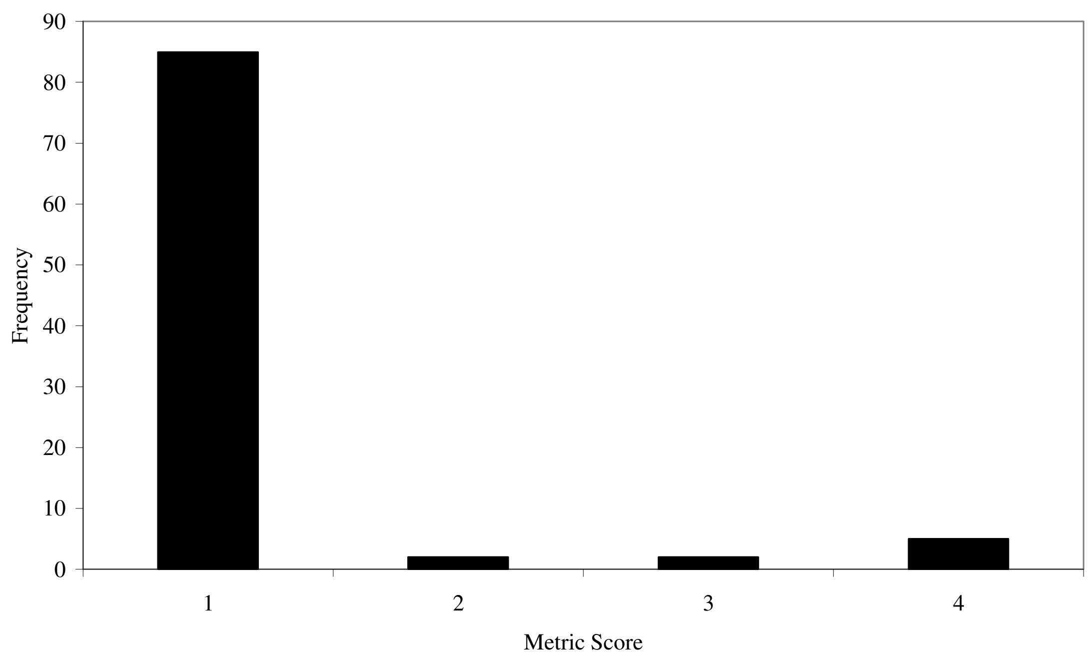

Cropland/agriculture
120
100
80
60
40
20
0
Frequency
1
2
3
4
5
Metric Score

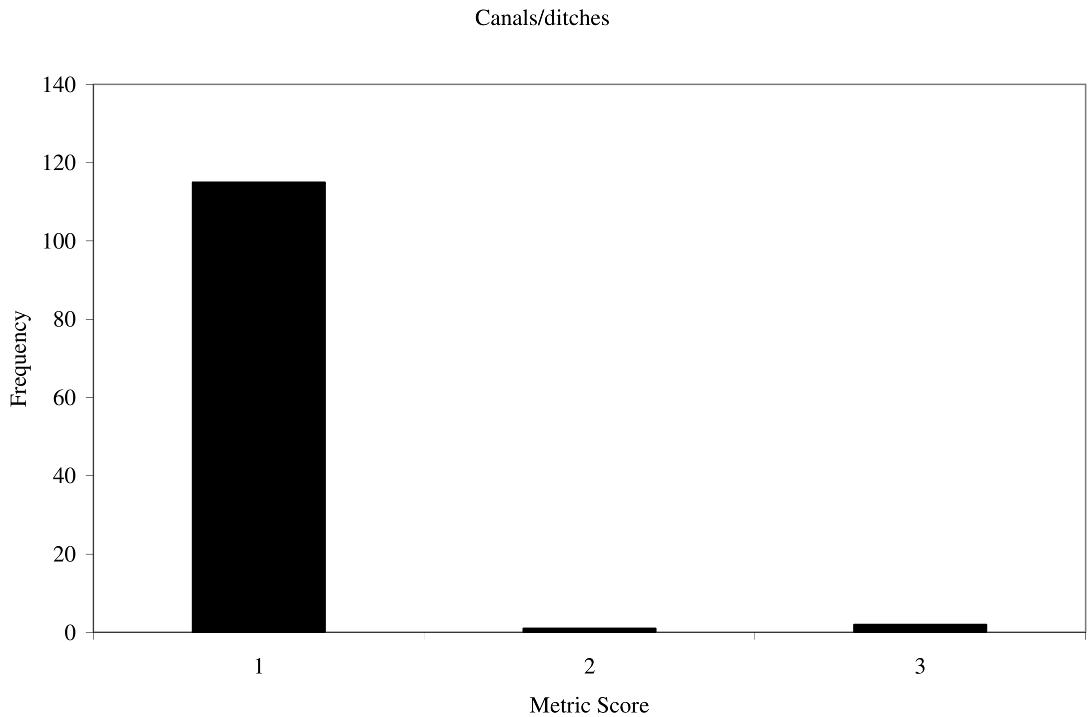

Cropland/agriculture
100
90
80
70
60
50
40
30
20
10
0
Frequency
1
2
3
4
5
Metric Score

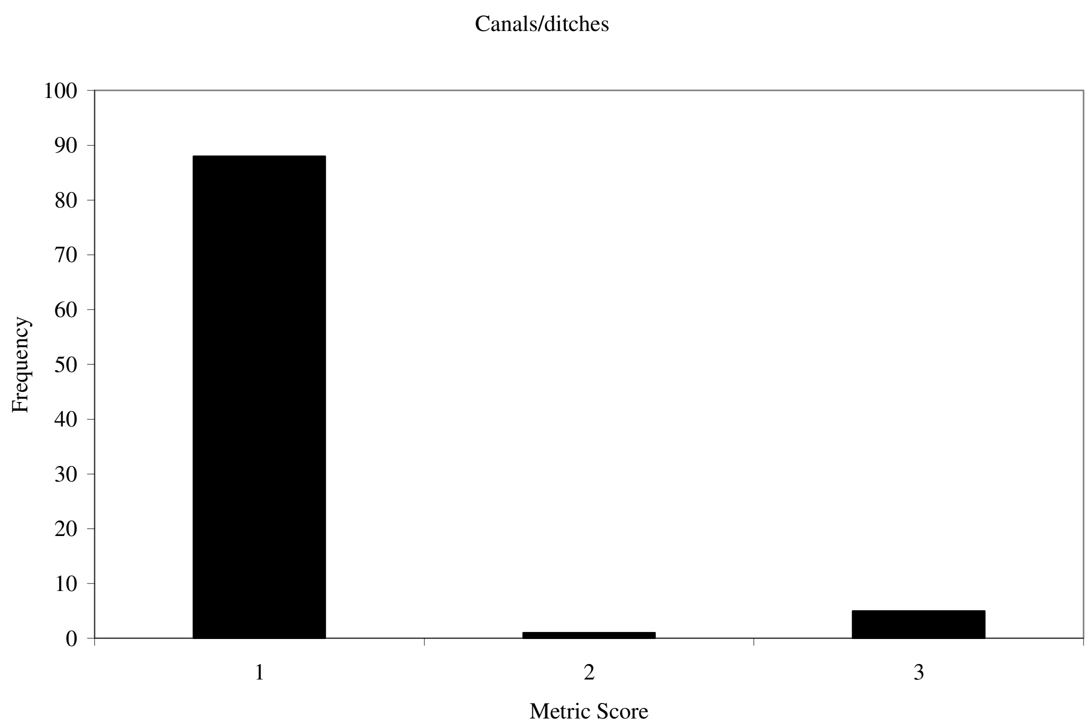
Hay pasture



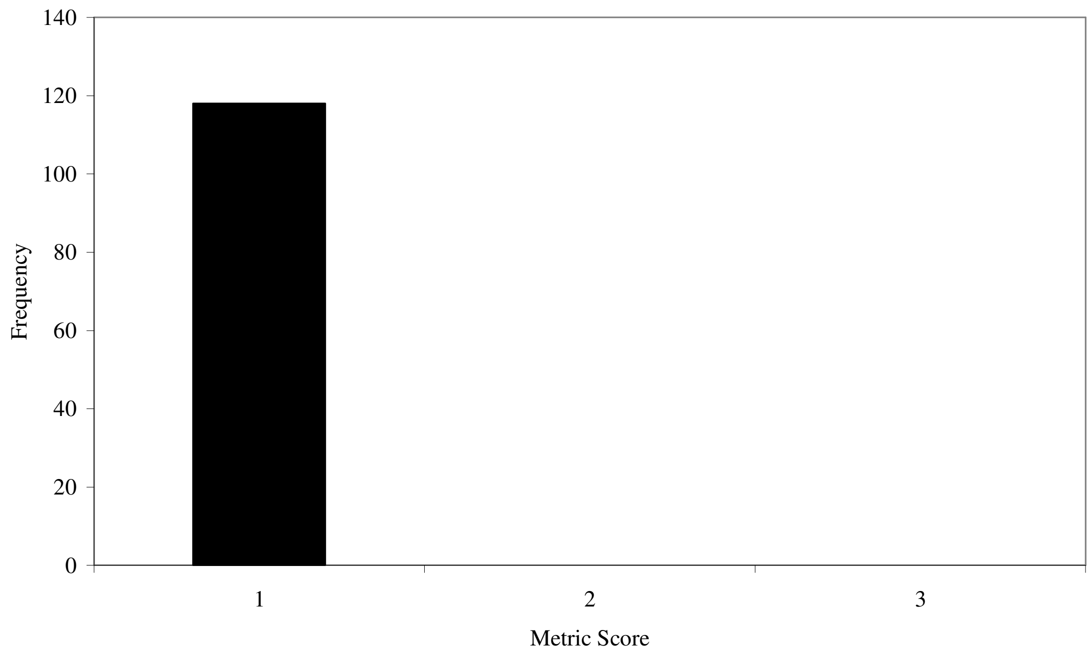
Hay pasture



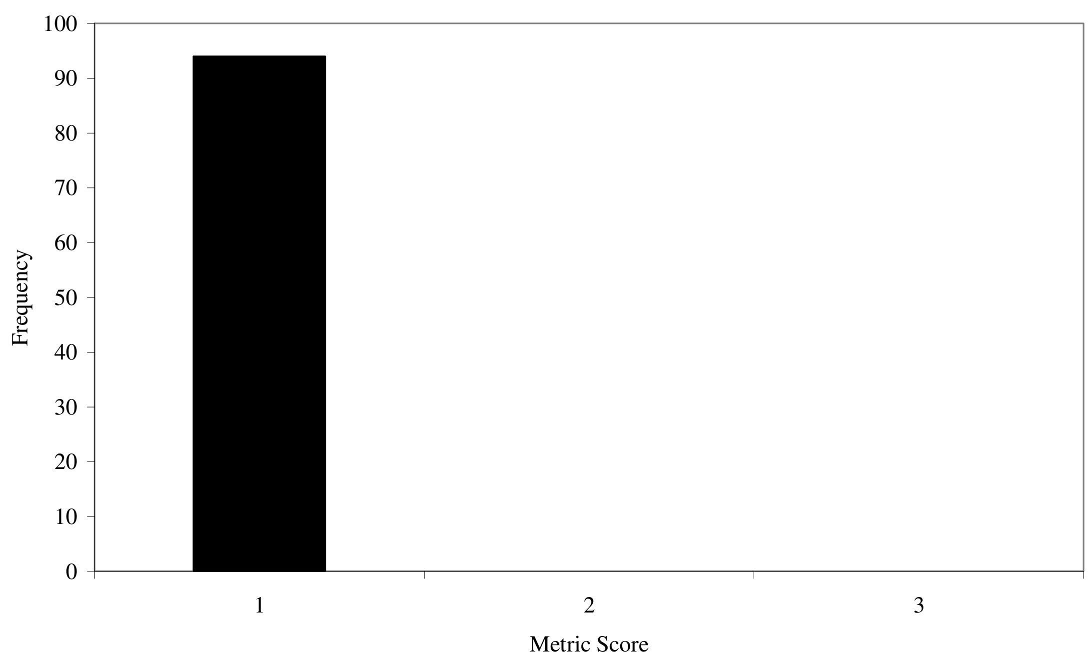

Canals/ditches
140
120
100
80
60
40
20
0
Frequency
1
2
3
Metric Score

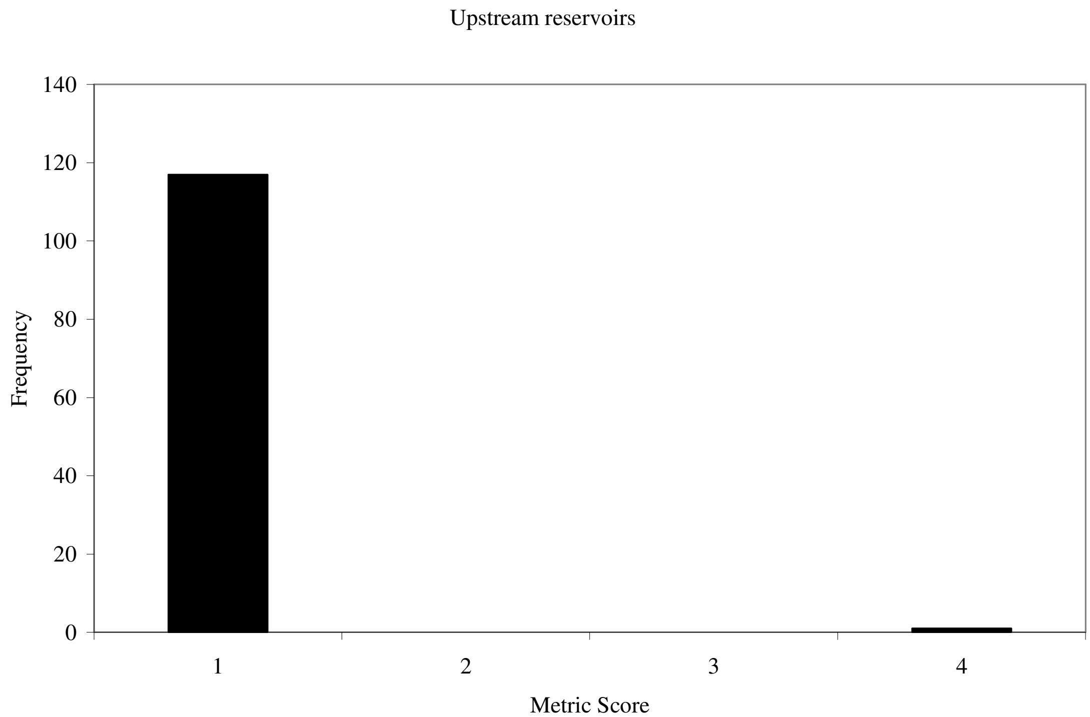

Canals/ditches
100
90
80
70
60
50
40
30
20
10
0
Frequency
1
2
3
Metric Score

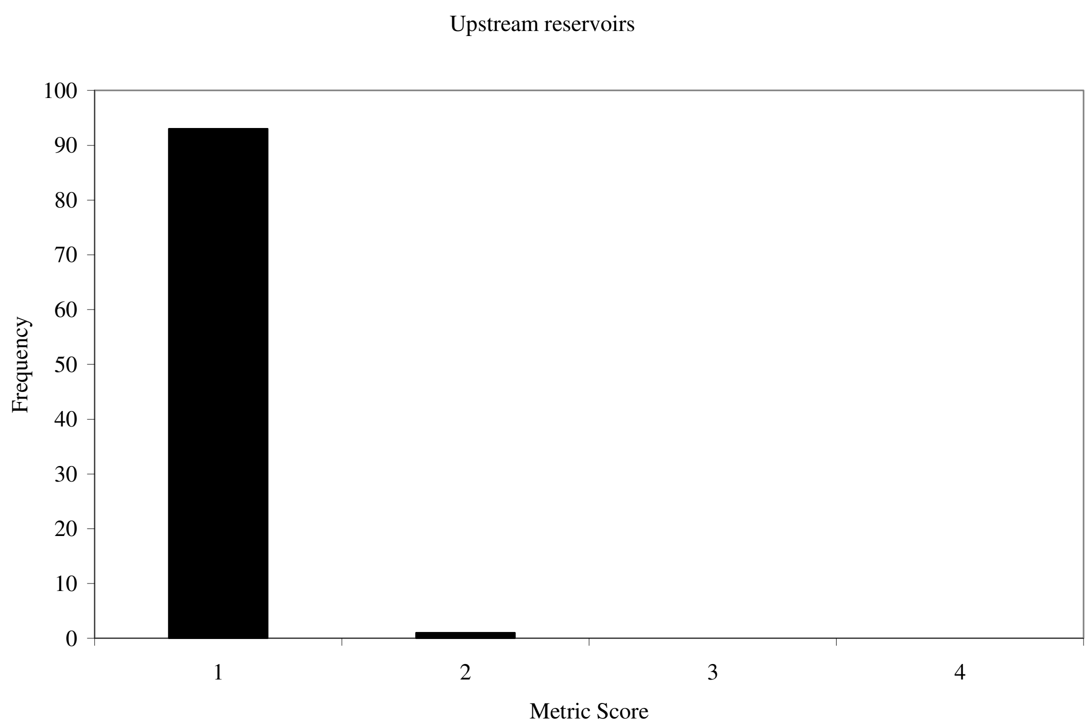
Wells


140
120
100
80
60
40
20
0
Frequency
1
2
3
Metric Score

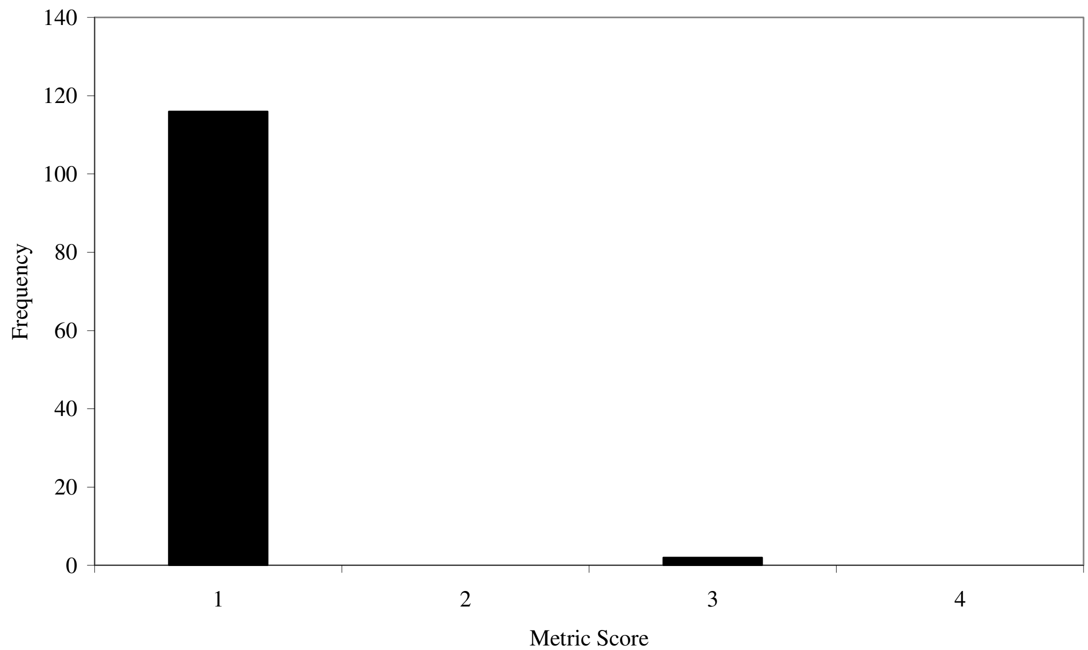
Wells


100
90
80
70
60
50
40
30
20
10
0
Frequency
1
2
3
Metric Score

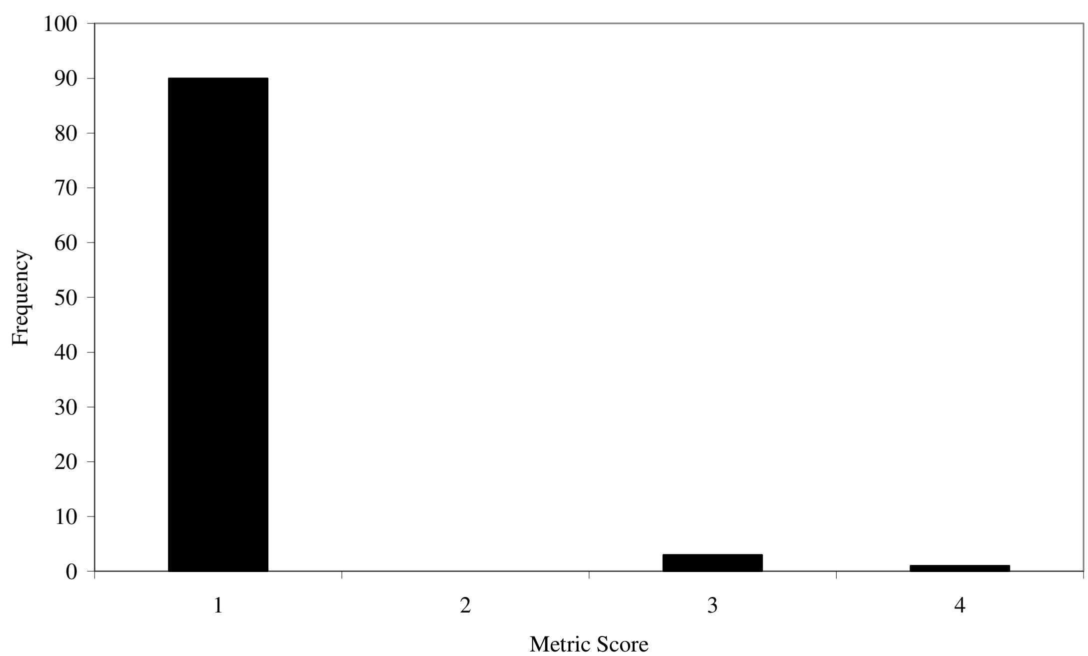

Upstream reservoirs
Frequency
0
20
40
60
80
100
120
140
1
2
3
4
Metric Score

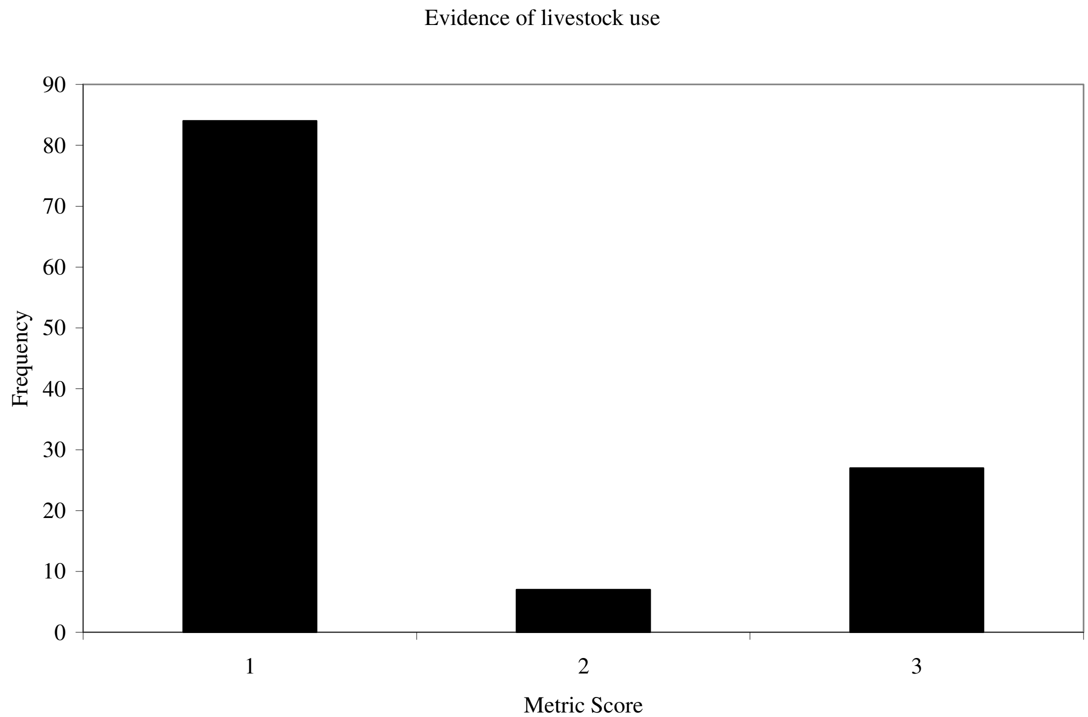

Upstream reservoirs
Frequency
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
Metric Score

Resource extraction

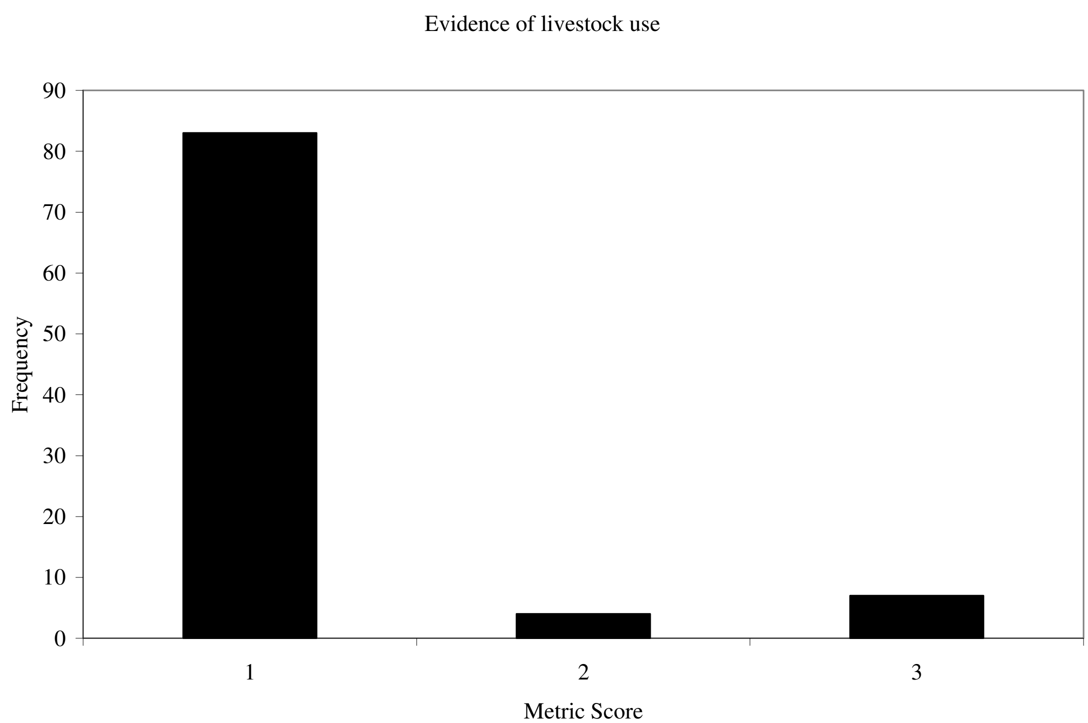


Resource extraction



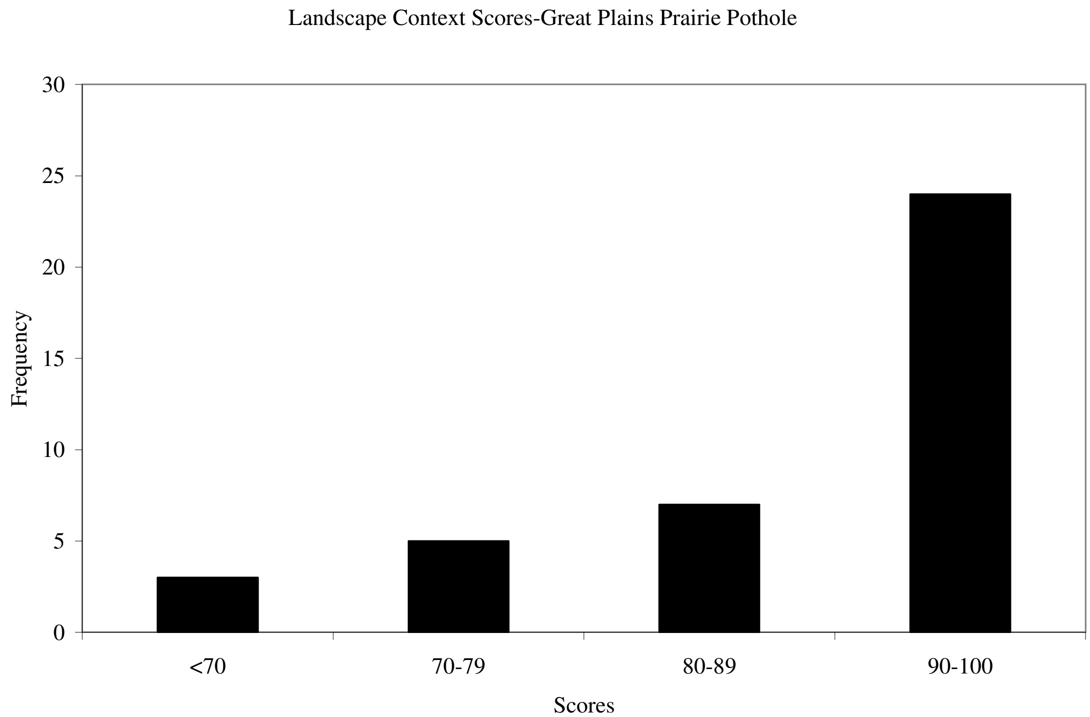


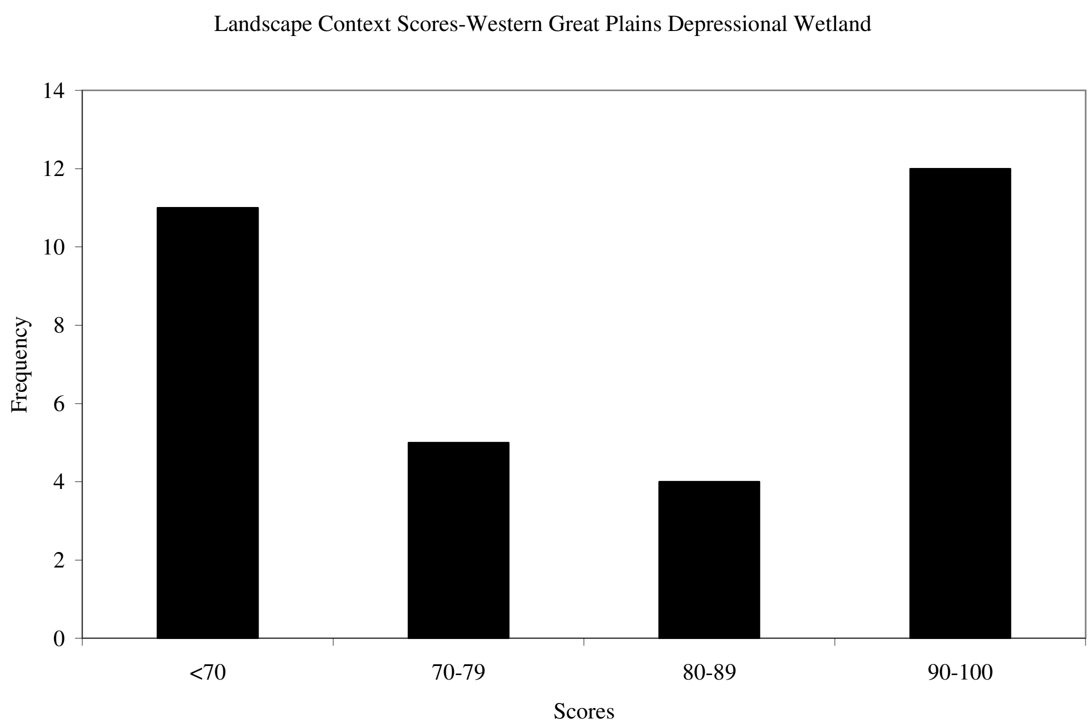
Evidence of livestock use
90
80
70
60
50
40
30
20
10
0
Frequency
1
2
3
Metric Score



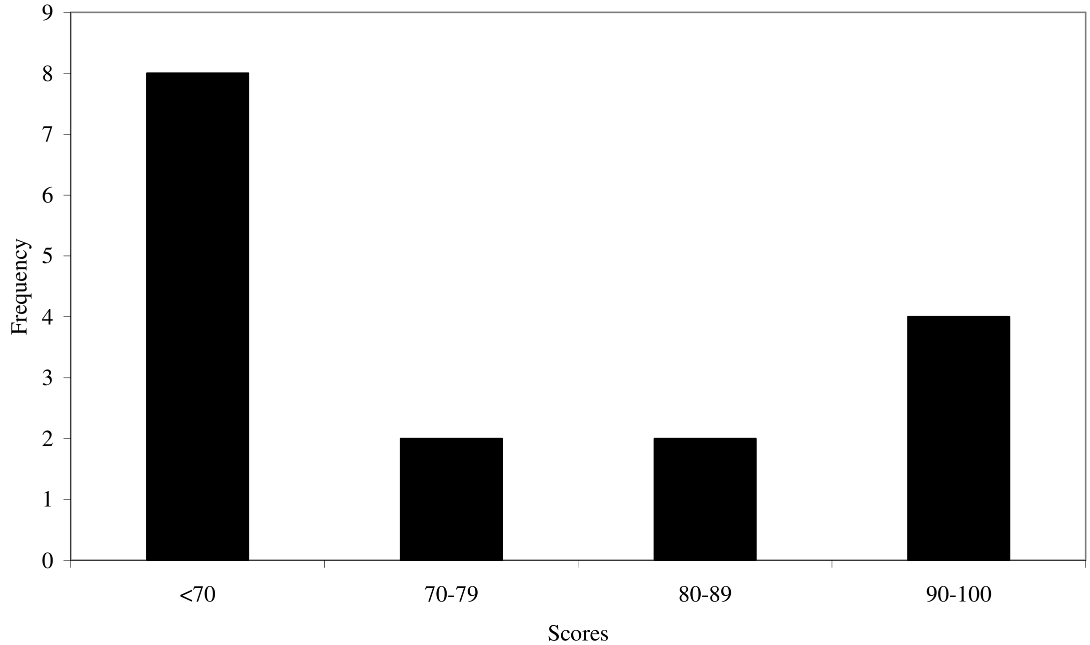
Evidence of livestock use
90
80
70
60
50
40
30
20
10
0
Frequency
1
2
3
Metric Score

Appendix F. Level 2 Attribute and Overall Condition Score Frequency Histograms for each Wetland Ecological System

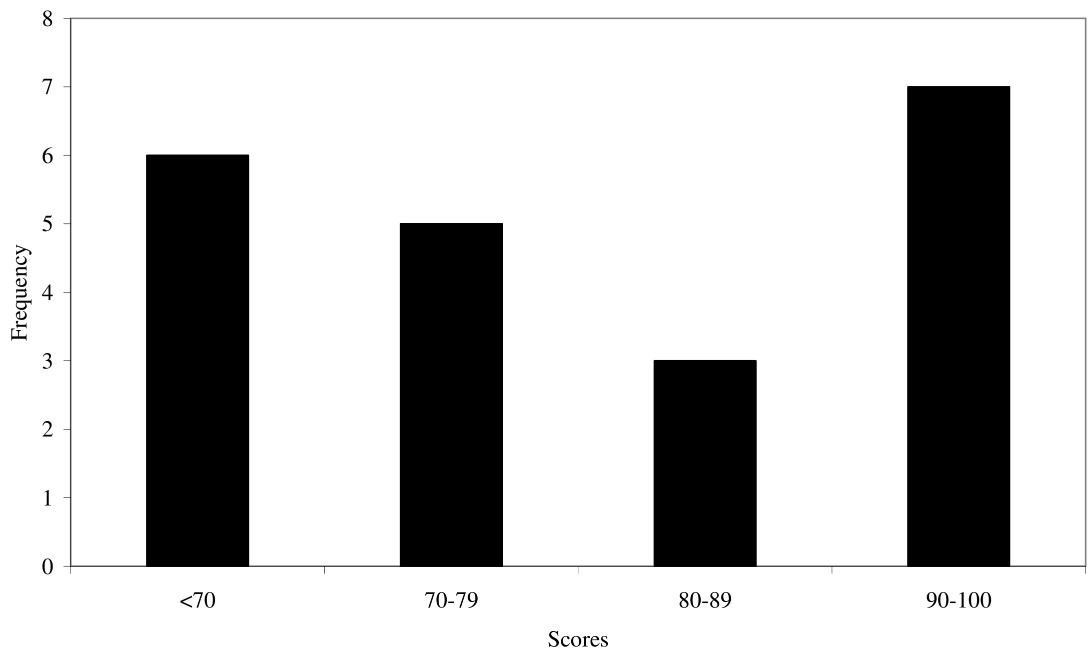

Landscape Context Scores-Great Plains Prairie Pothole
Frequency
30
25
20
15
10
5
0
<70
70-79
80-89
90-100
Scores


Landscape Context Scores-Western Great Plains Depressional Wetland
Frequency
14
12
10
8
6
4
2
0
<70
70-79
80-89
90-100
Scores

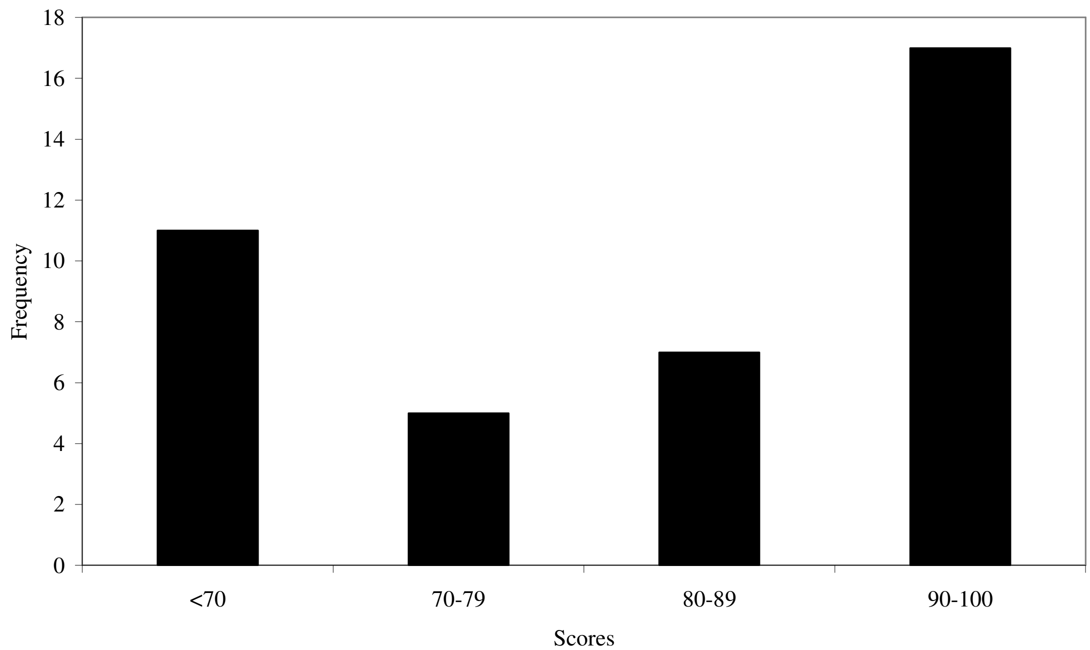
Landscape Context Scores-Western Great Plains Saline Depression Wetland



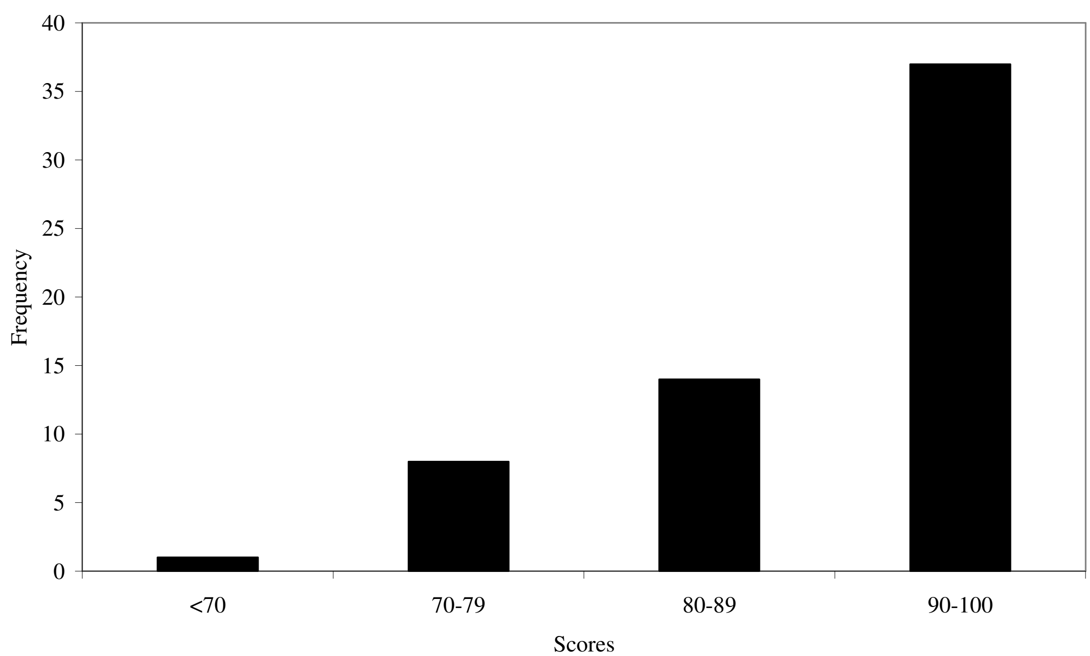
Landscape Context Scores-Rocky Mountain Subalpine-Montane Fen



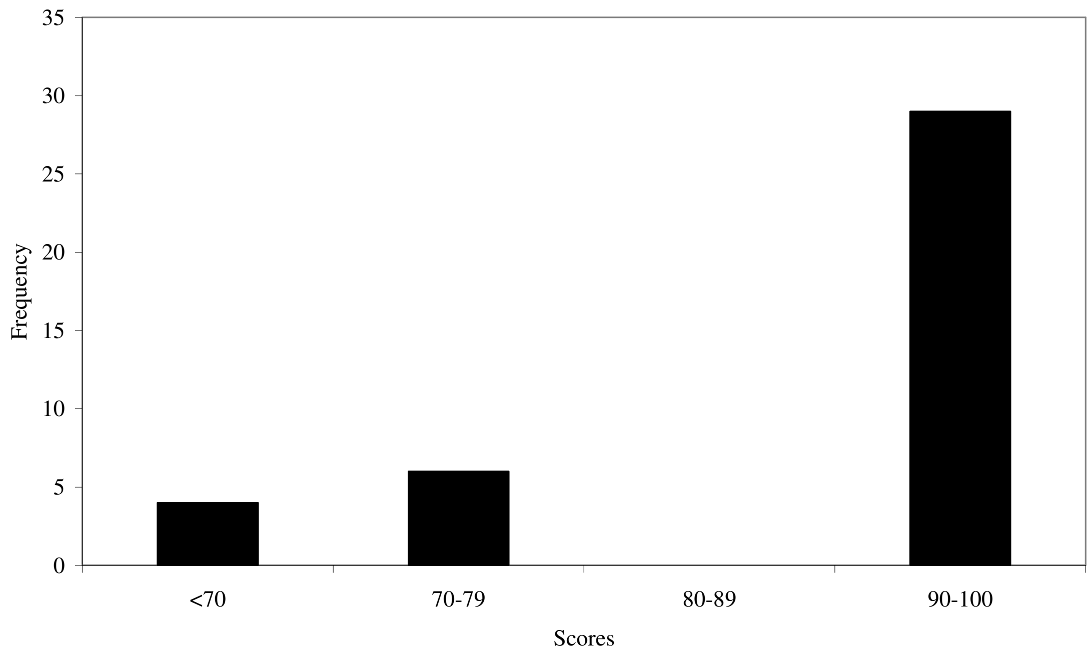
Landscape Context Scores-Western North American Emergent Marsh



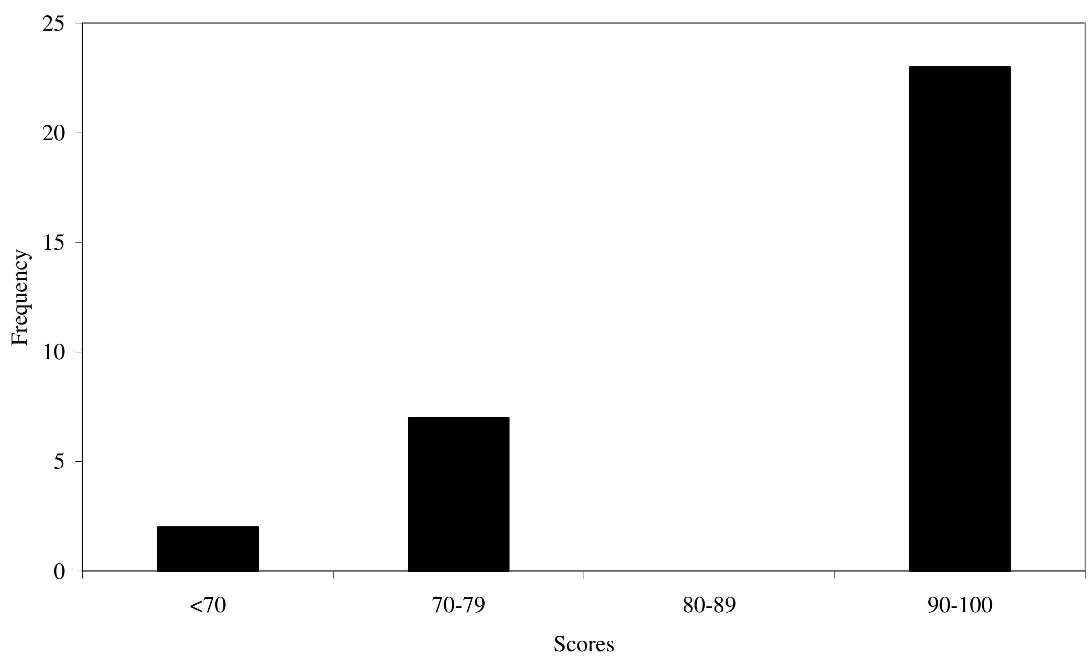
Overall Condition Scores-Rocky Mountain Alpine-Montane Wet Meadow



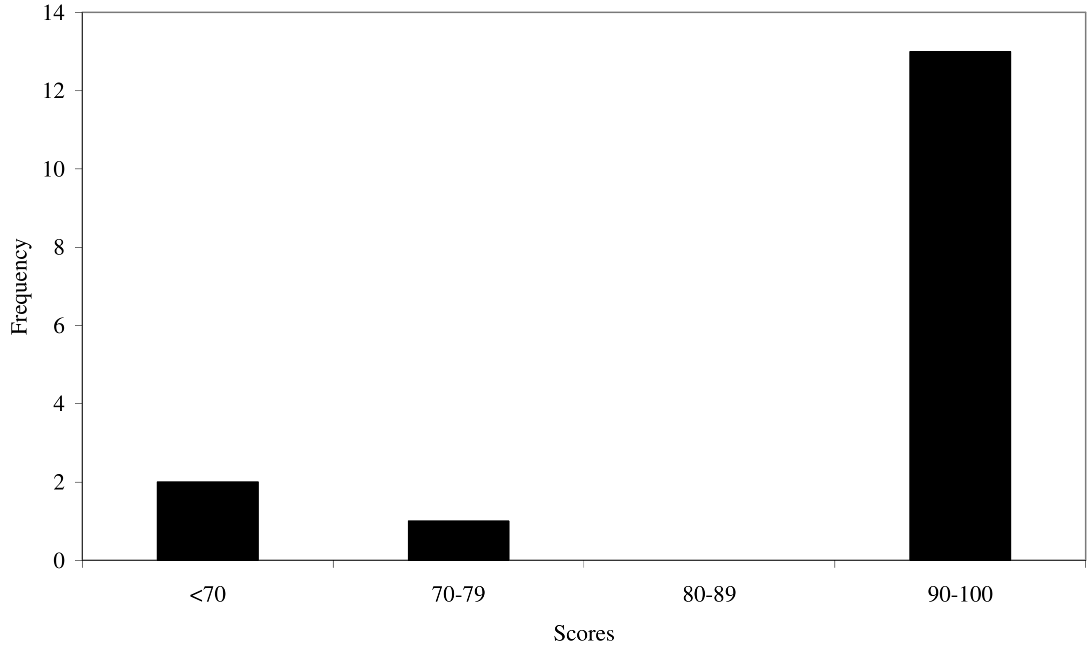
Relative Wetland Size Scores-Great Plains Prairie Pothole



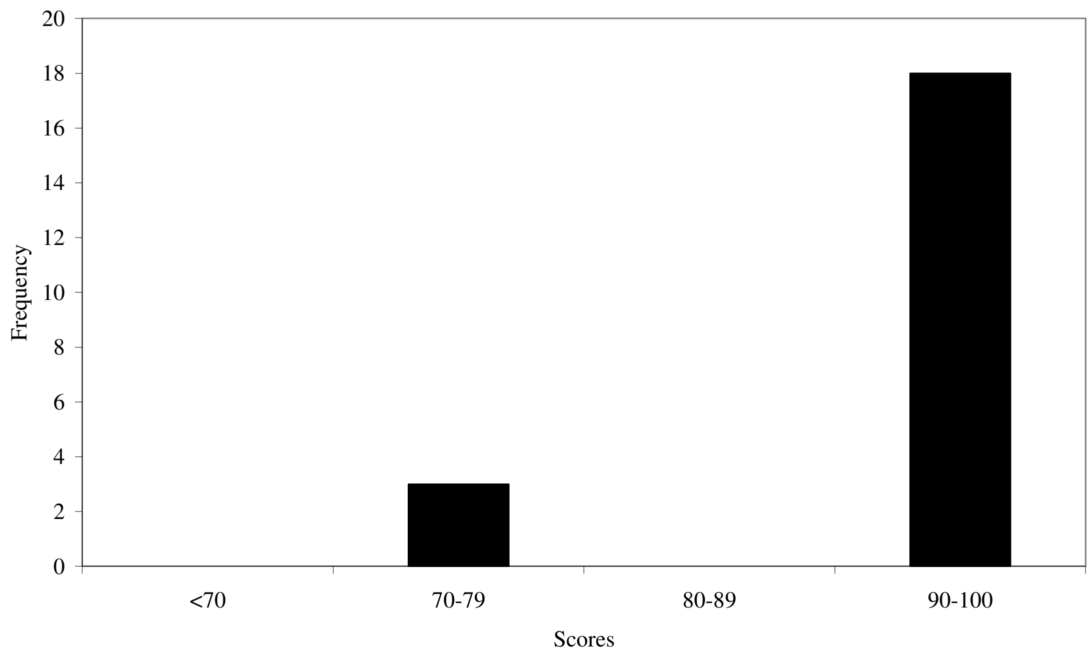
Relative Wetland Size Scores-Western Great Plains Depressional Wetland



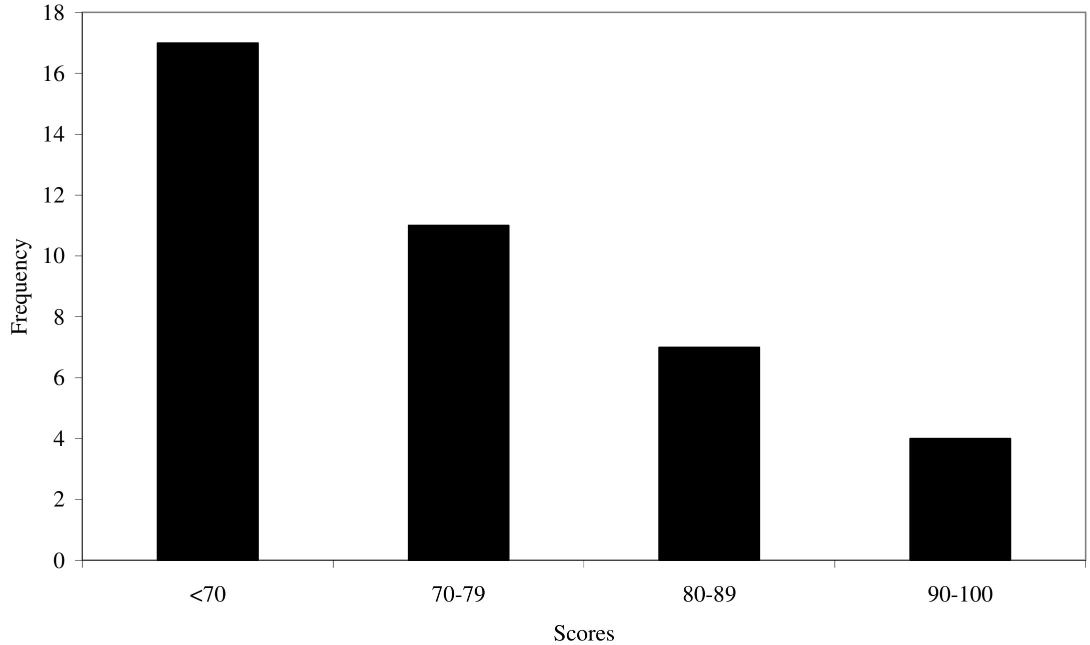
Relative Wetland Size Scores-Western Great Plains Saline Depression Wetland



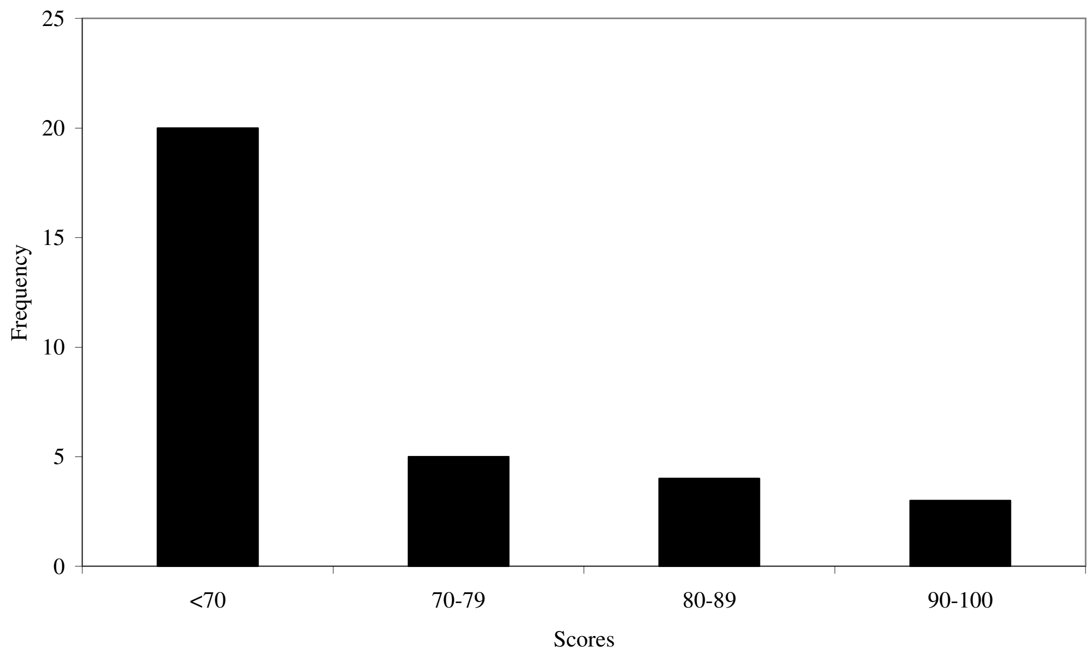
Relative Wetland Size Scores-Rocky Mountain Subalpine-Montane Fen



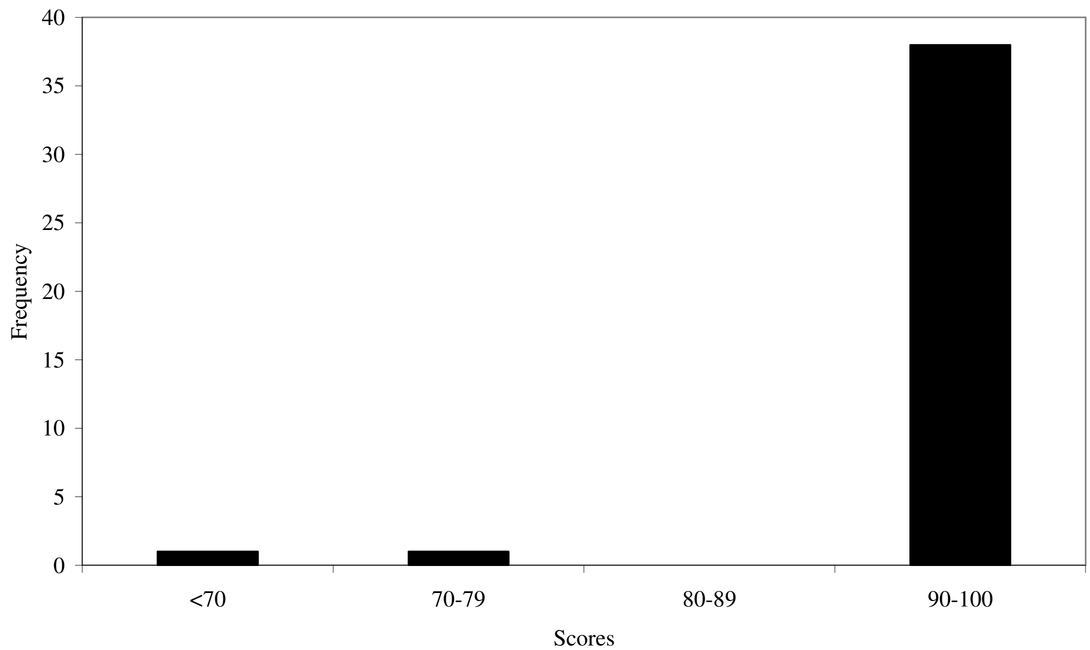
Biotic Composition and Structure Scores-Great Plains Prairie Pothole



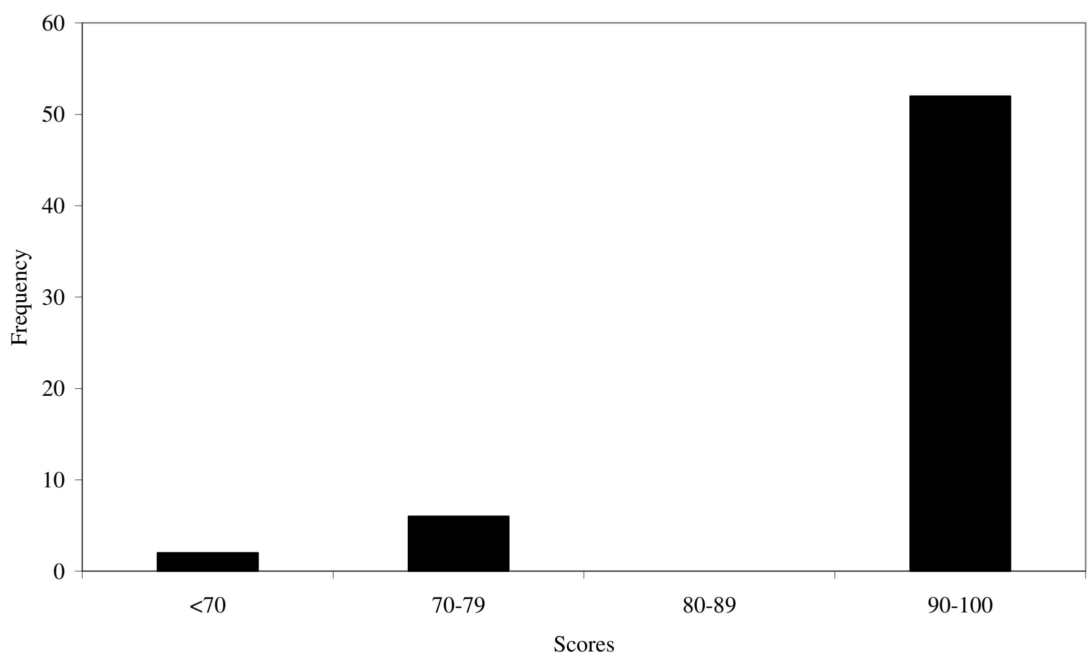
Biotic Composition and Structure Scores-Western Great Plains Depressional Wetland



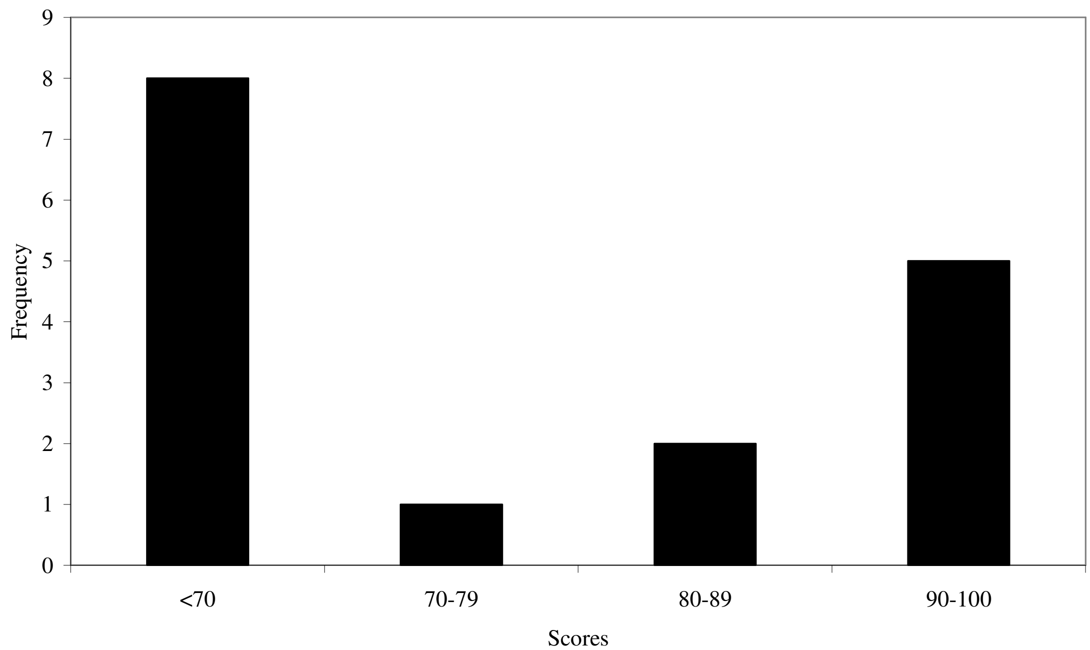
Relative Wetland Size Scores-Western North American Emergent Marsh



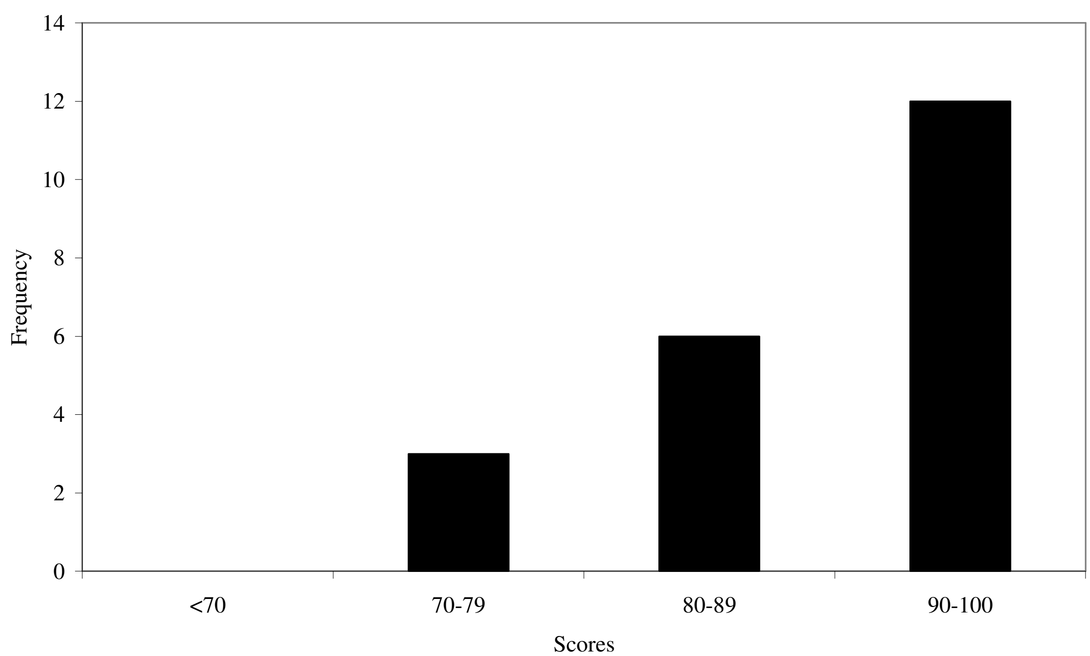
Relative Wetland Size Scores-Rocky Mountain Alpine-Montane Wet Meadow



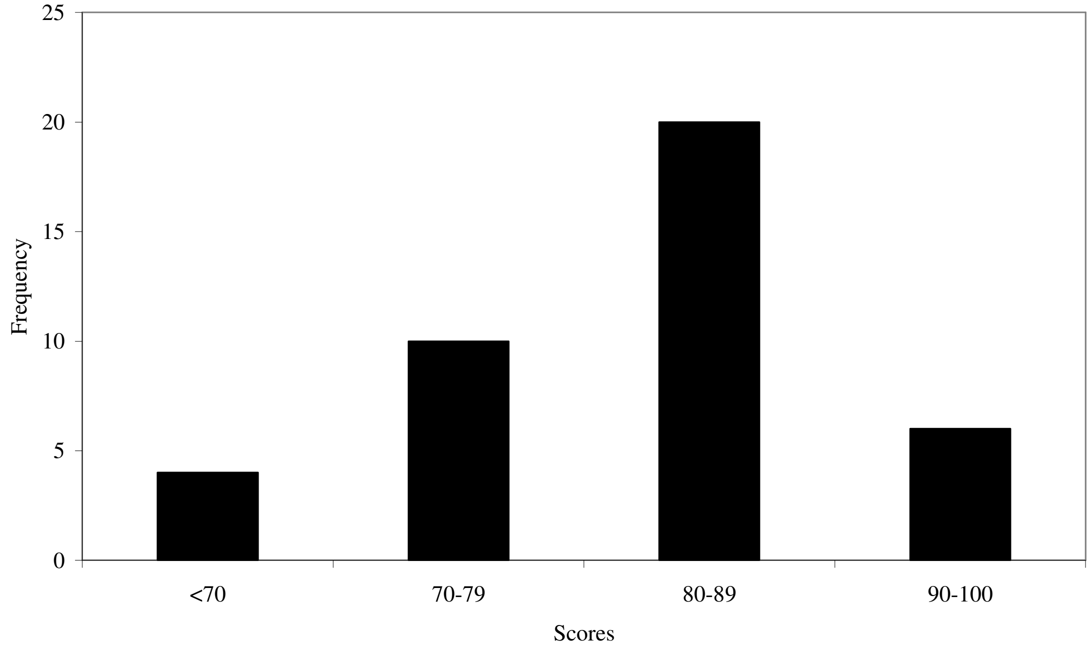
Biotic Composition and Structure Scores-Western Great Plains Saline Depression Wetland



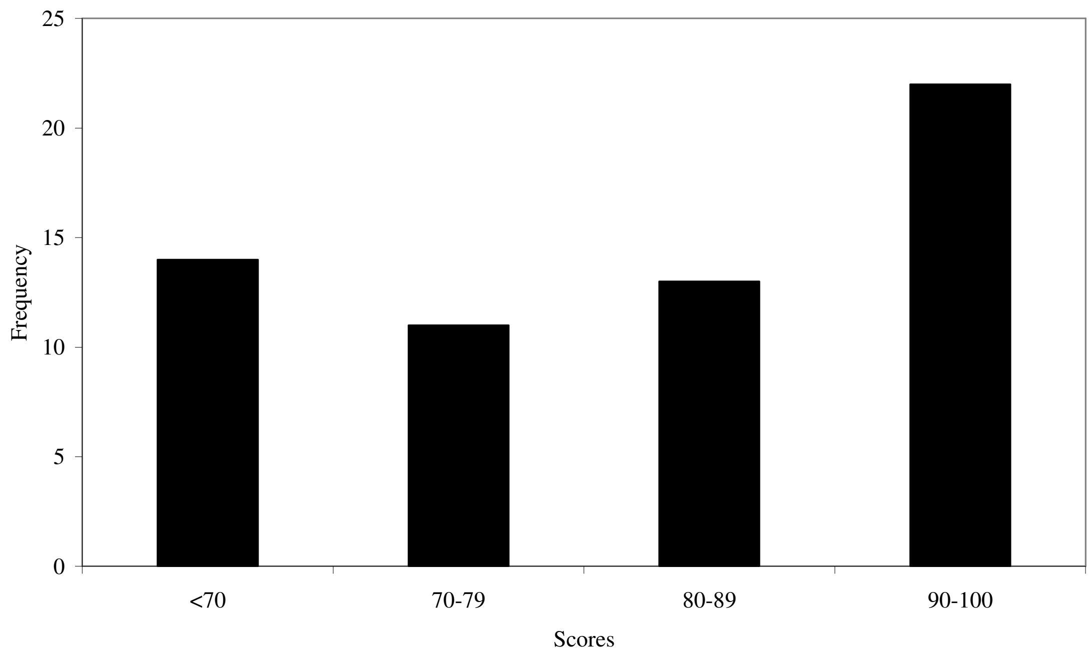
Biotic Composition and Structure Scores-Rocky Mountain Subalpine-Montane Fen



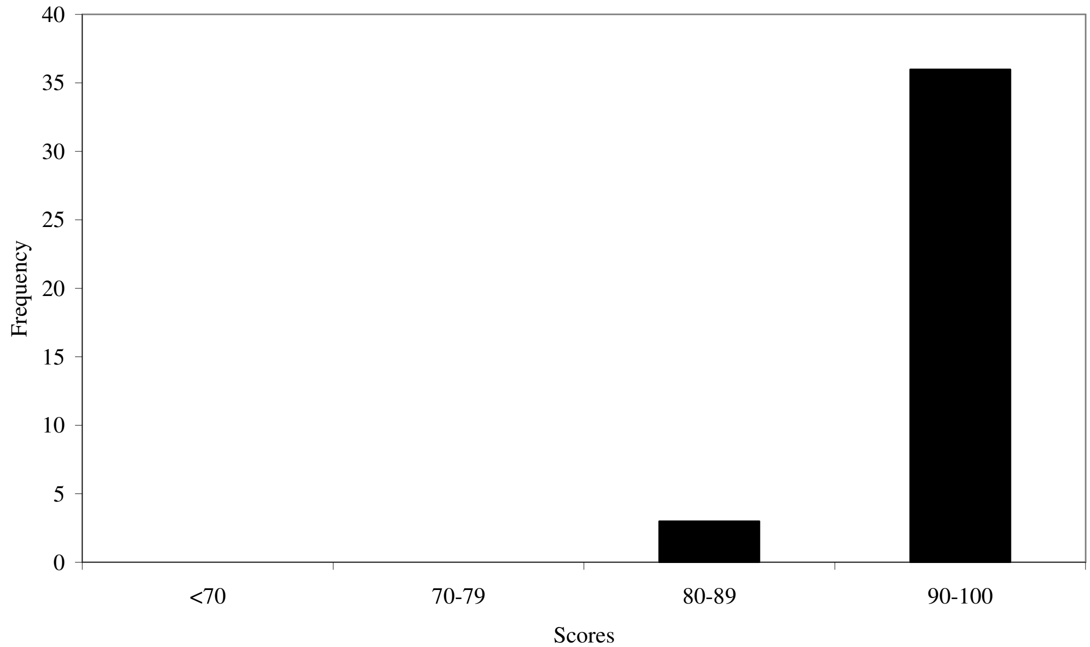
Biotic Composition and Structure Scores-Western North American Emergent Marsh



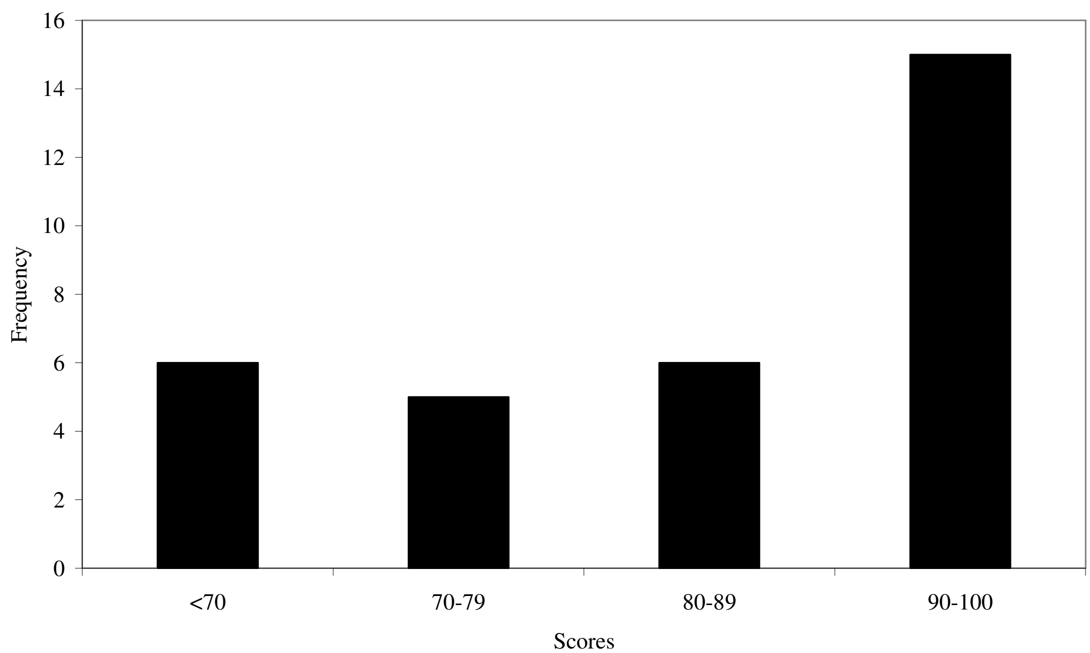
Biotic Composition and Structure Scores-Rocky Mountain Alpine-Montane Wet Meadow



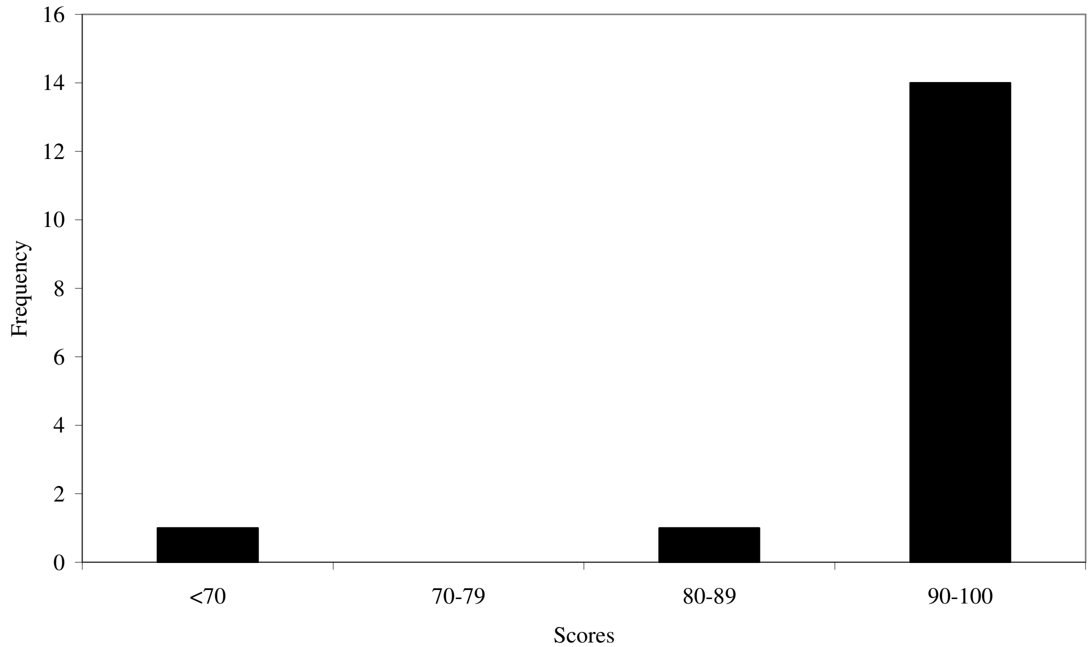
Hydrology Scores-Great Plains Prairie Pothole



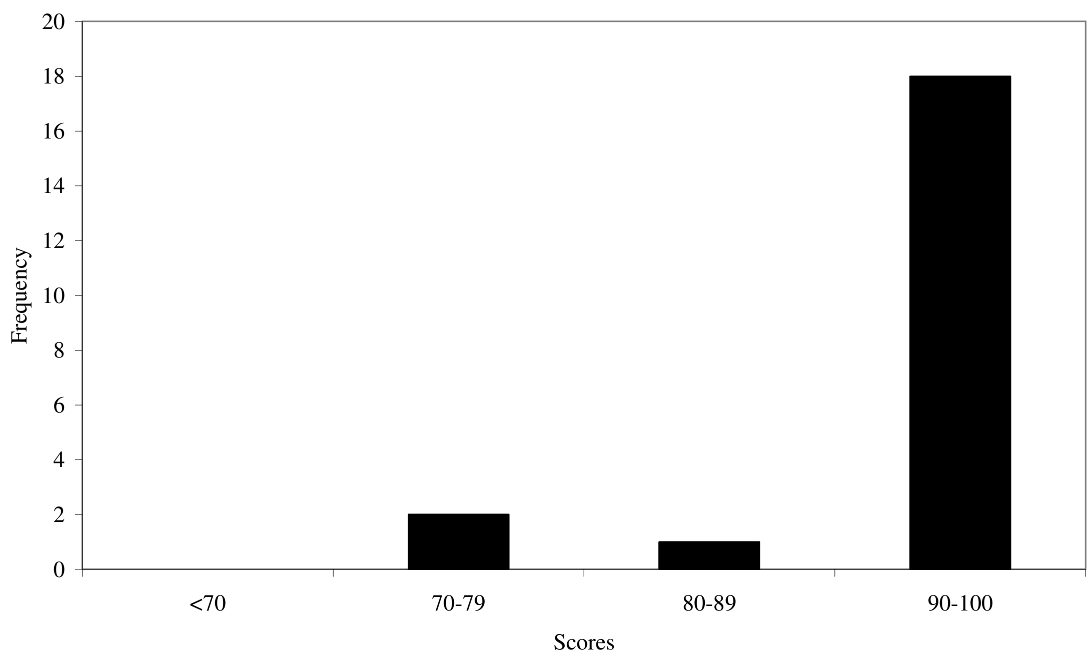
Hydrology Scores-Western Great Plains Depressional Wetland



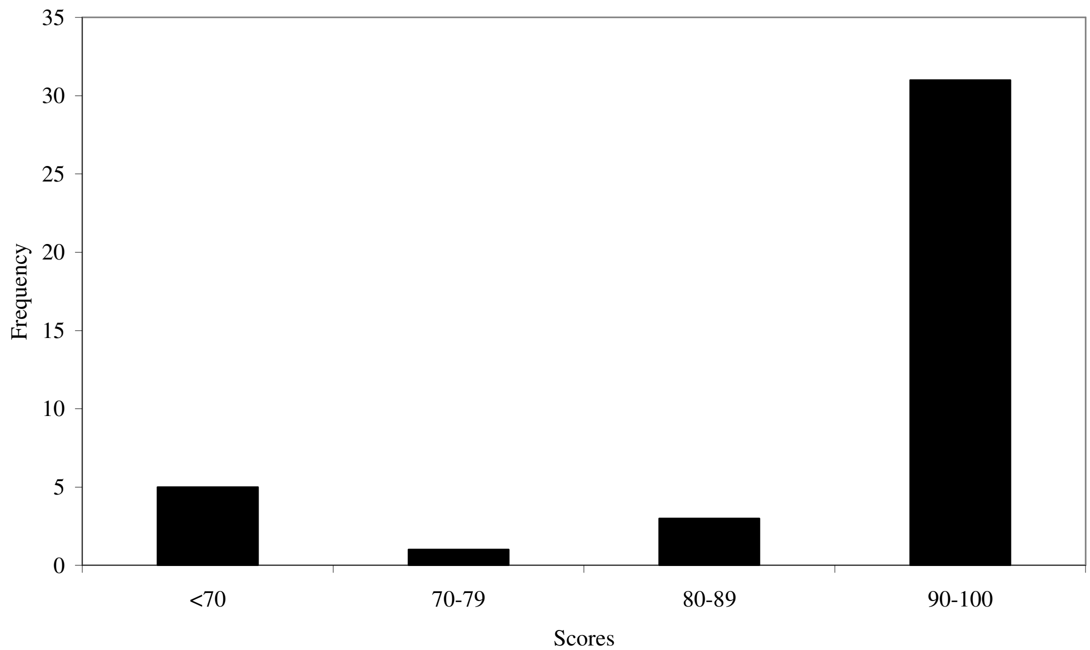
Hydrology Scores-Western Great Plains Saline Depression Wetland



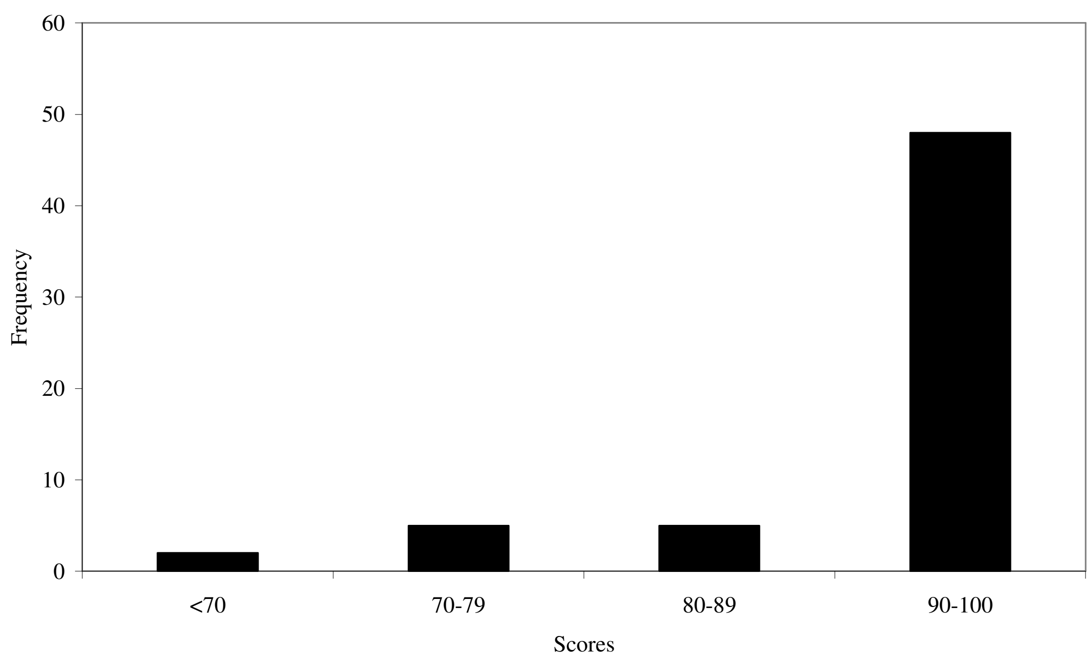
Hydrology Scores-Rocky Mountain Subalpine-Montane Fen



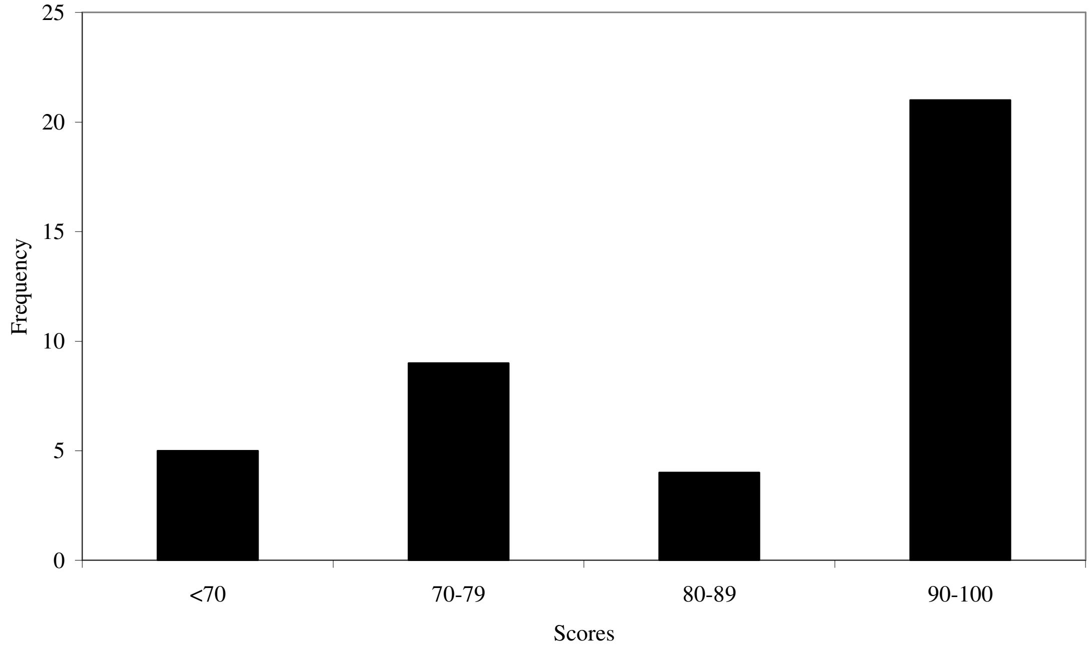
Hydrology Scores-Western North American Emergent Marsh



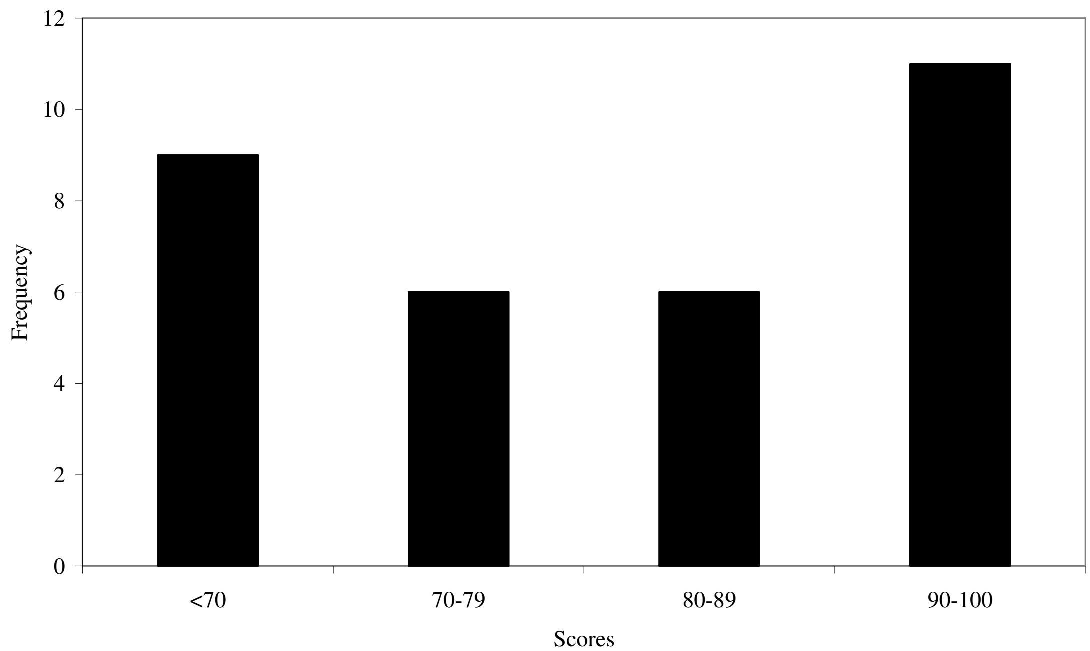
Hydrology Scores-Rocky Mountain Alpine-Montane Wet Meadow



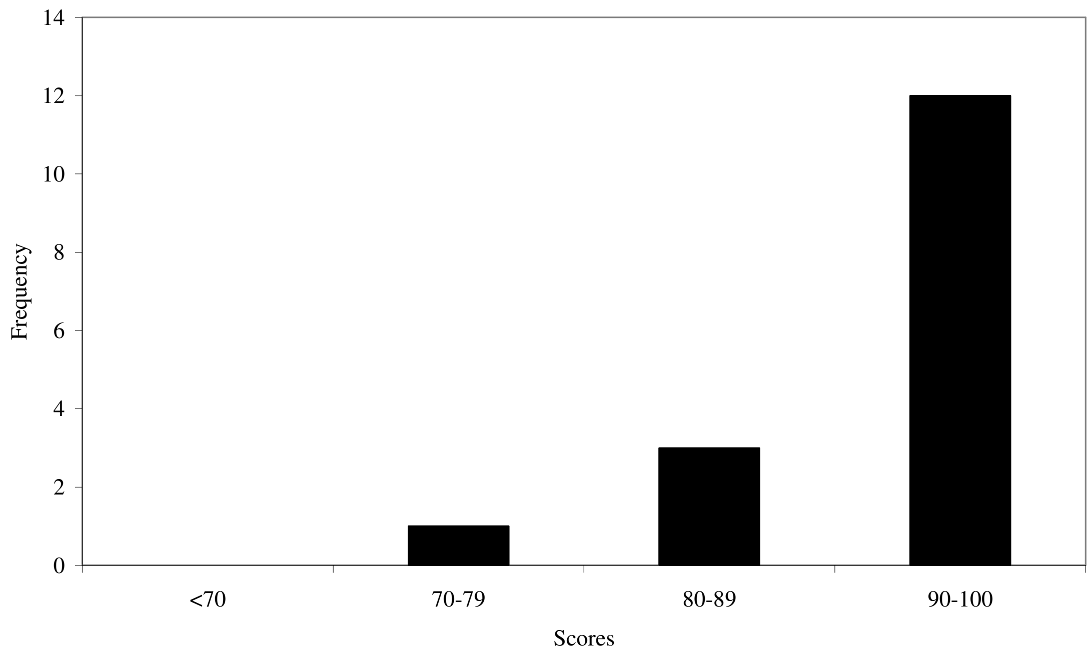
Physicochemical Scores-Great Plains Prairie Pothole



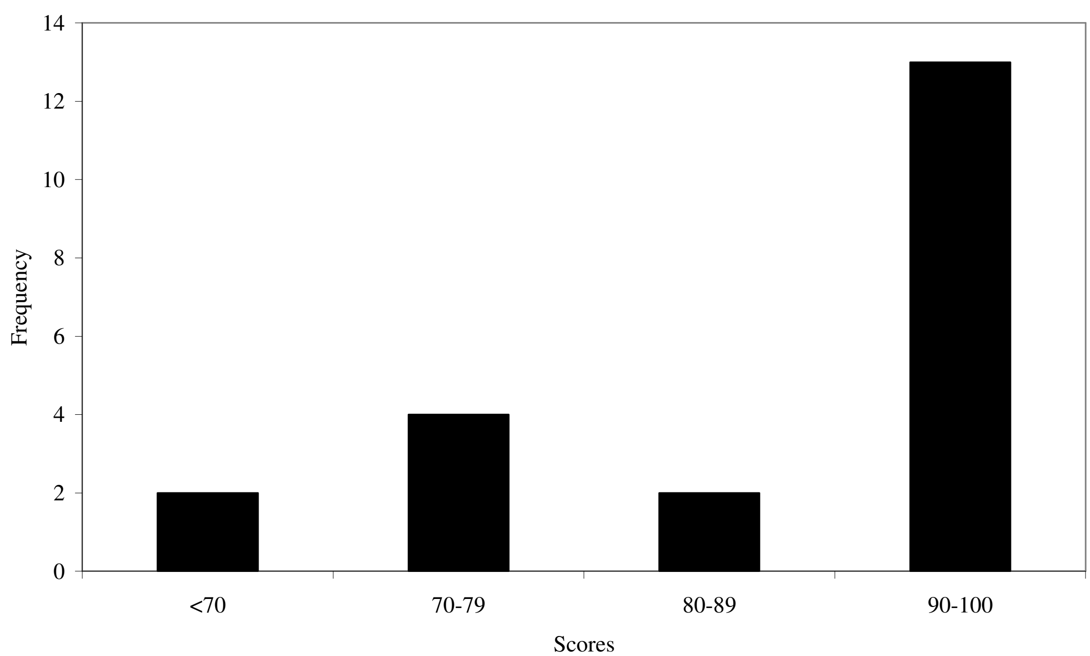
Physicochemical Scores-Western Great Plains Depressional Wetland



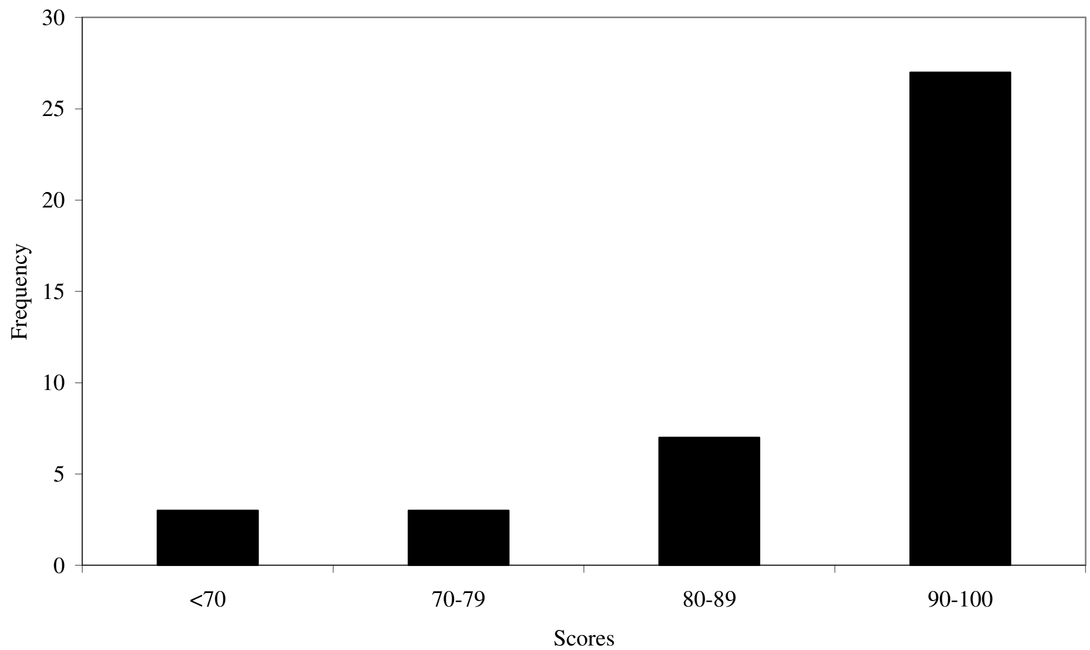
Physicochemical Scores-Western Great Plains Saline Depression Wetland



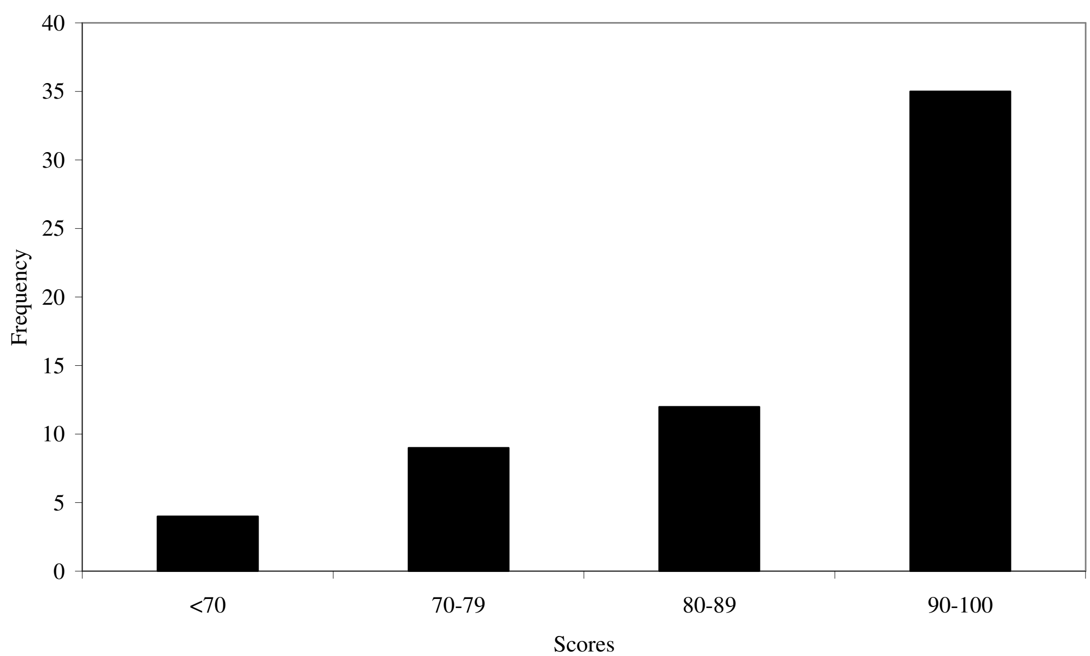
Physicochemical Scores-Rocky Mountain Subalpine-Montane Fen



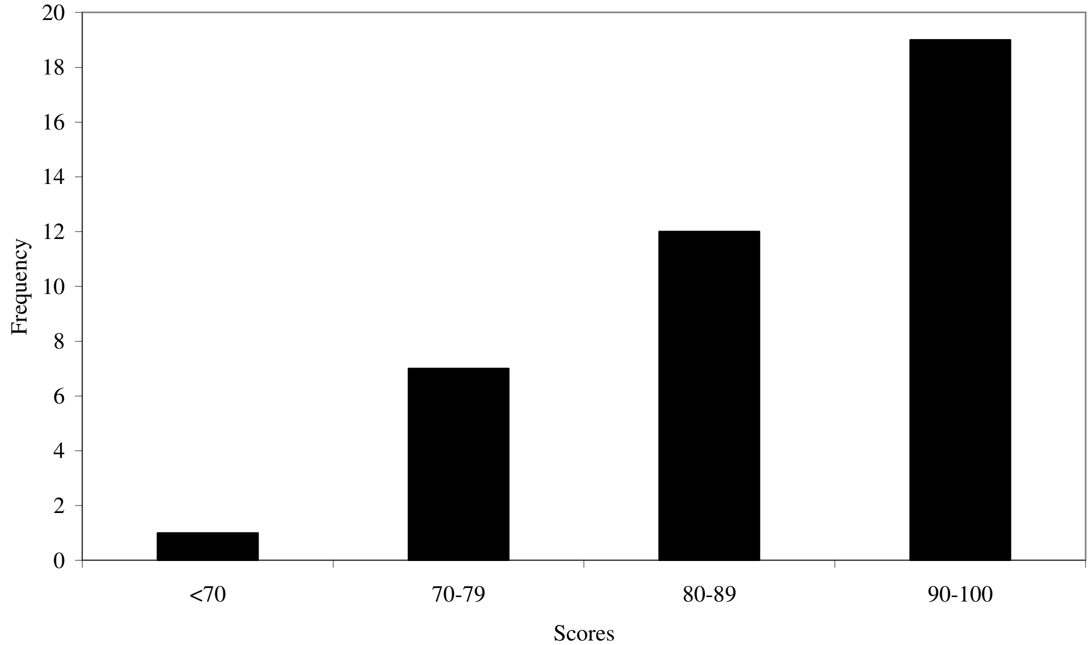
Physicochemical Scores-Western North American Emergent Marsh



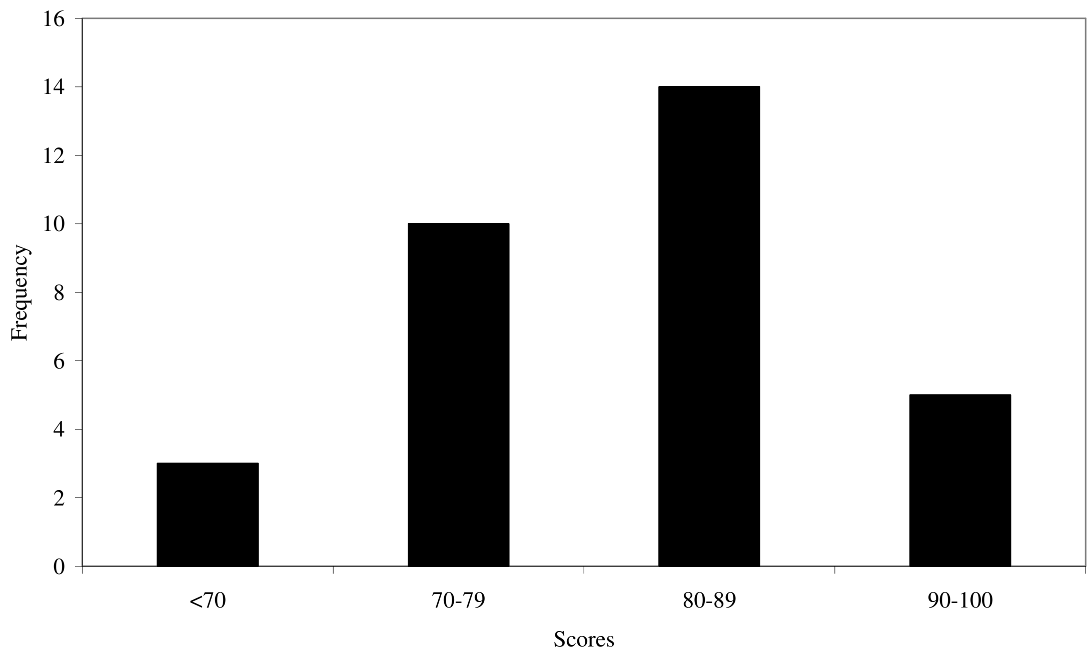
Physicochemical Scores-Rocky Mountain Alpine-Montane Wet Meadow



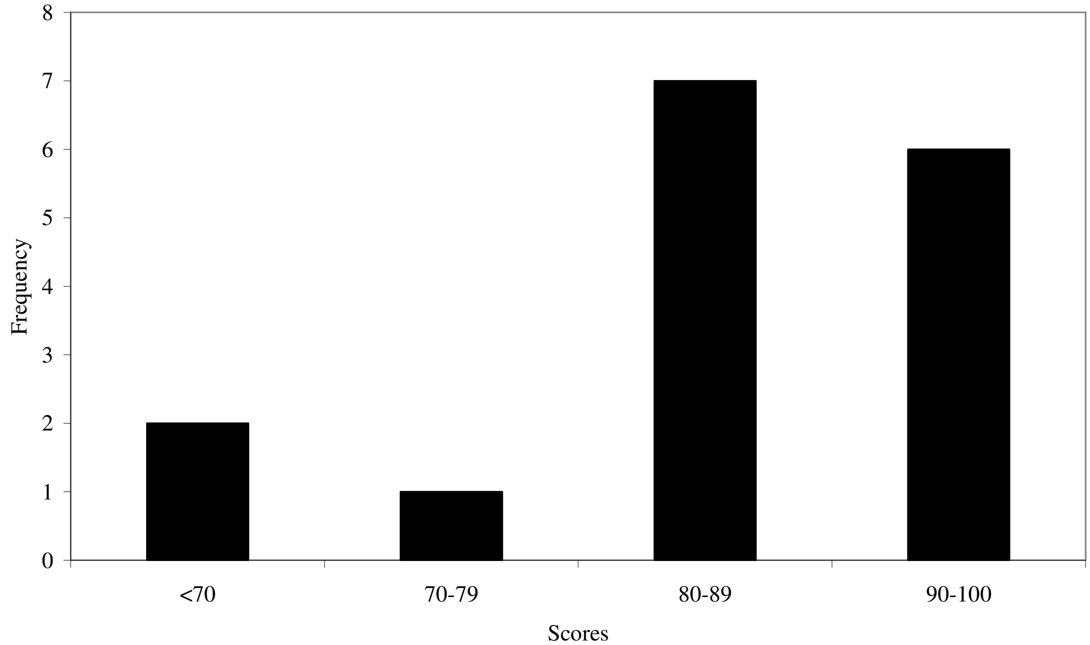
Overall Condition Scores-Great Plains Prairie Pothole



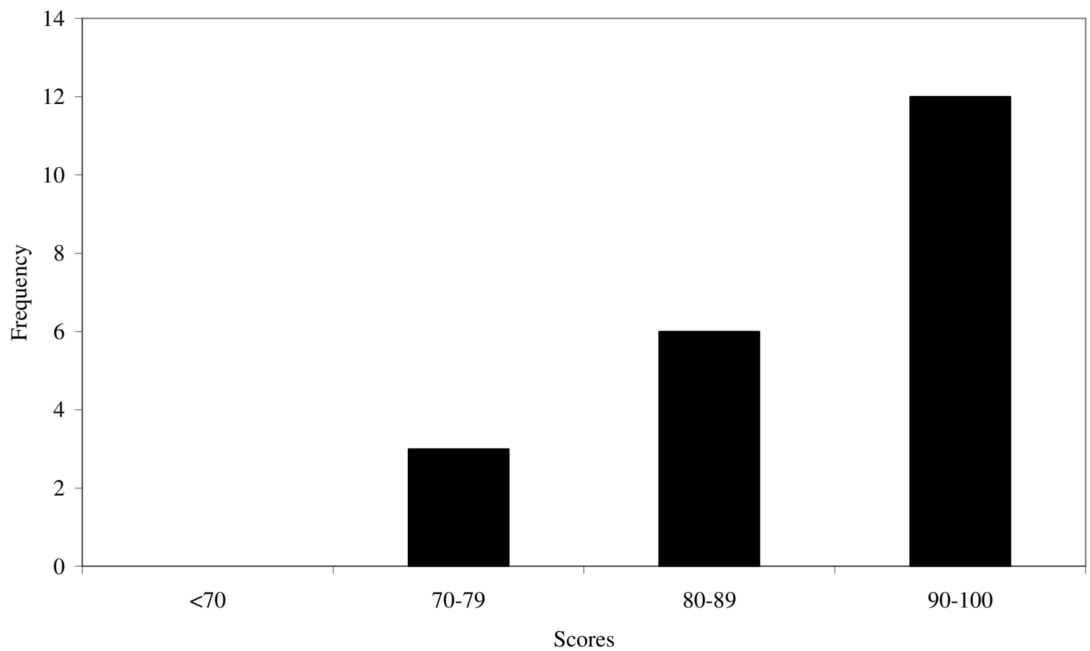
Overall Condition Scores-Western Great Plains Depressional Wetland



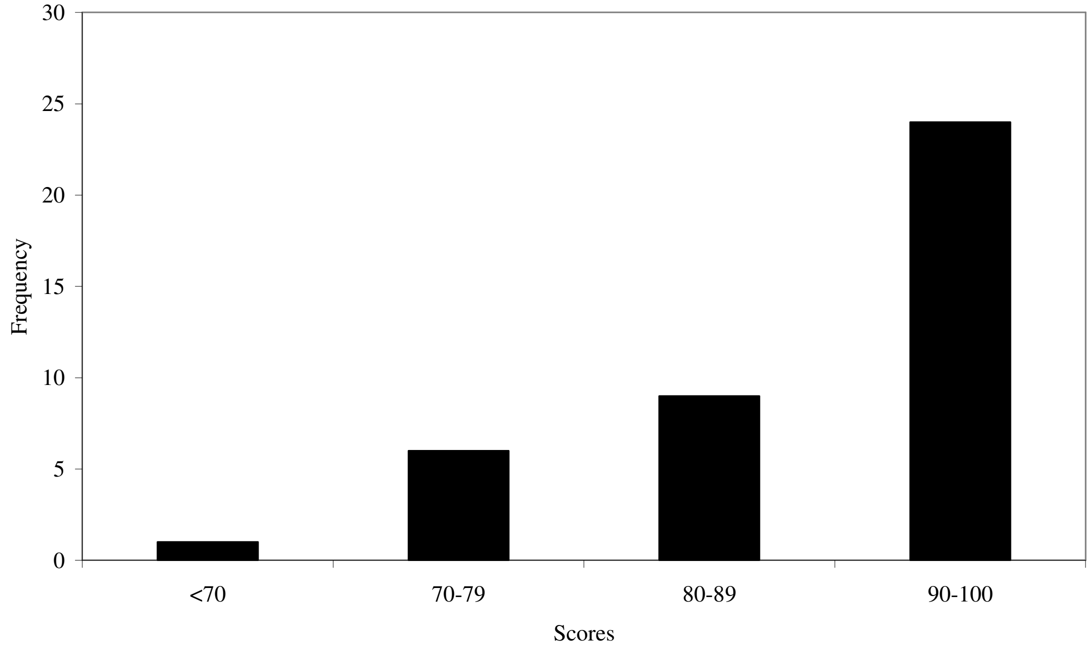
Overall Condition Scores-Western Great Plains Saline Depression Wetland



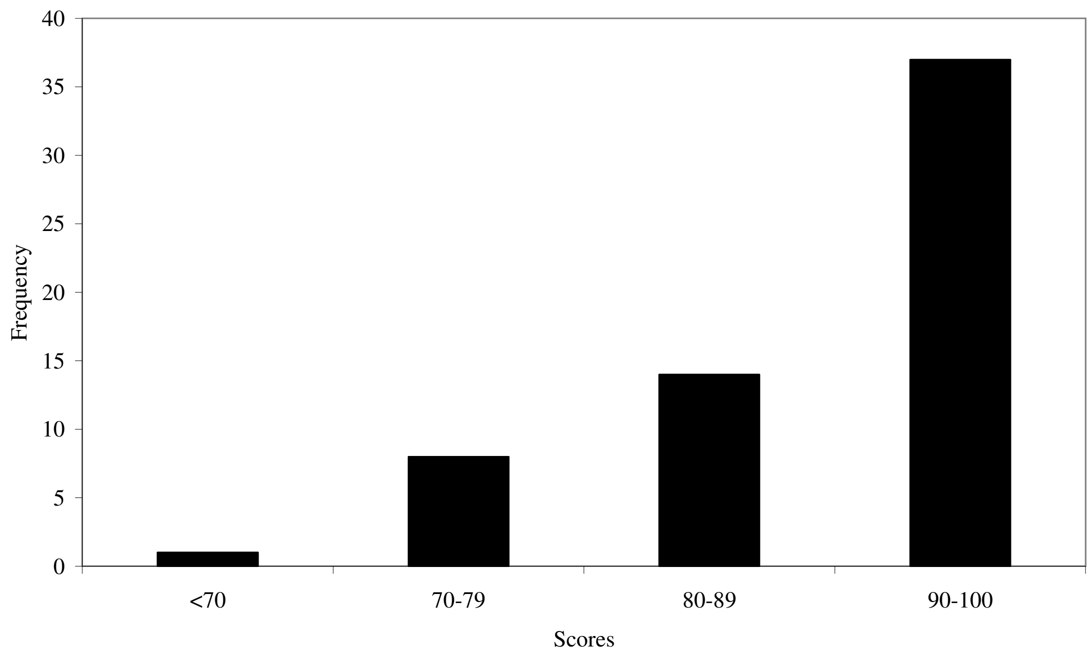
Overall Condition Scores-Rocky Mountain Subalpine-Montane Fen



Overall Condition Scores-Western North American Emergent Marsh



Overall Condition Scores-Rocky Mountain Alpine-Montane Wet Meadow



Appendix G. Validation of Wetland Assessment Methods

Wetlands of the Northwestern Great Plains and Northwestern Glaciated Plains

Correlation coefficients between Level 1 metrics and Level 2 attribute and overall condition scores were primarily negative; however, few correlations were significant at α ≤ 0.10 and relationships were weak (Table 1). Landscape Context and Hydrology showed significant negative relationships with local roads, highways, land cover/land use metrics, and resource use. The Physicochemical attribute had no significant relationships with any Level 1 metric. Biotic Composition and Structure had a negative relationship with cropland/agriculture but a positive relationship with hay pasture. Relative size was negatively correlated with local roads, cropland/agriculture, and canals/ditches. Only local roads, highways, and cropland/agriculture had significant negative correlations with overall wetland condition.

Relationships between Level 1 and Level 2 scores were variable and inconsistent depending upon Cowardin water regime. The Landscape Context and Relative Size attributes as well as overall condition scores were negatively correlated with local roads for both temporary (Table 2) and seasonal wetlands (Table 3). Semi-permanent wetlands showed relationships that were inconsistent with our expected relationships (Table 4).

Table 1. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for herbaceous wetlands in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions. Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	0.02	0.00	0.00	-0.08	-0.10	-0.06
local road	**-0.31**	**-0.19**	-0.06	**-0.28**	-0.04	**-0.26**
highway	**-0.29**	-0.06	0.06	**-0.39**	-0.04	**-0.19**
low density development	-0.10	-0.04	0.11	**-0.20**	-0.09	-0.08
developed open space	**-0.21**	-0.03	0.06	-0.09	0.00	-0.04
cropland/agriculture	**-0.32**	**-0.26**	**-0.31**	-0.09	0.09	**-0.25**
hay pasture	-0.10	0.01	**0.18**	-0.08	0.01	0.04
canals/ditches	0.09	**-0.16**	-0.10	0.01	0.02	-0.02
resource extraction	-0.11	-0.08	0.12	**-0.21**	-0.04	-0.09
evidence of livestock use	**0.26**	0.00	0.08	0.11	0.10	0.16

Table 2. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for temporary wetlands in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions (n = 44). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	-0.09	-0.13	-0.23	0.12	-0.09	-0.19
local road	**-0.30**	**-0.38**	-0.10	-0.25	-0.12	**-0.31**
highway	**-0.38**	0.14	0.13	**-0.53**	-0.07	-0.24
developed open space	-0.23	0.11	0.02	0.12	0.20	0.06
cropland/agriculture	-0.24	**-0.27**	**-0.28**	-0.08	0.09	-0.22
evidence of livestock use	**0.27**	0.01	0.09	0.17	0.10	0.24

Table 3. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for seasonal wetlands in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions (n = 34). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	-0.02	-0.05	-0.06	-0.12	-0.19	-0.12
local road	**-0.45**	-0.08	**-0.36**	**-0.42**	-0.05	**-0.43**
highway	**-0.30**	-0.14	0.10	-0.26	0.01	-0.17
low density develoment	-0.15	-0.11	0.04	-0.28	-0.20	-0.21
developed open space	-0.28	-0.12	-0.05	-0.22	-0.15	-0.17
cropland/agriculture	**-0.29**	**-0.34**	-0.26	**-0.32**	**-0.32**	**-0.29**
hay pasture	-0.27	0.02	0.17	-0.12	-0.10	-0.11
canals/ditches	0.19	**-0.35**	-0.20	-0.09	-0.10	-0.16
upstream reservoir	-0.02	0.10	-0.07	**-0.30**	-0.27	-0.20
evidence of livestock use	0.01	-0.19	**-0.31**	0.10	0.27	-0.10

Table 4. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for semi-permanent wetlands in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions (n = 40). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	0.19	0.17	0.05	-0.11	-0.08	0.04
local road	-0.16	-0.08	0.07	-0.17	0.07	-0.05
highway	-0.23	-0.15	-0.02	**-0.3**	-0.04	-0.21
low density develoment	-0.08	0.07	0.2	-0.2	-0.05	-0.01
developed open space	-0.08	0.07	0.2	-0.2	-0.05	-0.01
cropland/agriculture	**-0.39**	-0.26	**-0.35**	0.05	**0.34**	-0.24
hay pasture	0.06	0.07	0.2	-0.03	0.16	0.21
canals/ditches	0.06	0.07	-0.09	0.15	0.16	0.14
resource extraction	-0.15	-0.19	0.19	**-0.29**	-0.07	-0.14
evidence of livestock use	**0.4**	0.25	**0.31**	0.06	-0.09	**0.31**

Relationships between Level 1 and Level 2 scores were also variable depending upon wetland ecological system. The Western Great Plains Depressional Wetland systems had significant negative correlations between several Level 1 land use metrics and the Level 2 Landscape Context, Relative Size, and Biotic Composition and Structure attributes (Table 5). Great Plains Prairie Potholes had several significant negative relationships between Level 1 metrics and Level 2 Hydrology attribute scores (Table 6). Western Great Plains Saline Depression Wetlands had significant negative relationships between Level 1 road metrics and Level 2 Physicochemical and Relative Size attribute scores (Table 7).

Table 5. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for Western Great Plains Open and Closed Depressional Wetland systems (n = 31). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	0.19	-0.03	0.24	-0.13	-0.09	0.13
local road	-0.12	-0.12	0.08	-0.08	-0.03	-0.09
highway	**-0.34**	-0.02	-0.28	-0.11	0.11	-0.24
developed open space	**-0.31**	**-0.37**	-0.24	-0.24	**-0.32**	**-0.31**
cropland/agriculture	**-0.41**	**-0.47**	**-0.48**	-0.03	0.12	-0.27
canals/ditches	0.27	-0.23	-0.06	0.26	0.12	0.20
upstream reservoirs	0.03	0.12	0.13	-0.15	-0.20	-0.06
evidence of livestock use	**0.44**	0.13	0.07	-0.07	0.21	0.27

Table 6. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for Great Plains Prairie Pothole systems (n = 39). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	0.08	0.09	-0.23	0.08	**-0.28**	-0.19
local road	**-0.69**	**-0.37**	-0.18	**-0.63**	-0.06	**-0.47**
highway	**-0.28**	-0.16	0.05	**-0.68**	-0.02	-0.17
low density development	-0.19	-0.24	-0.14	**-0.29**	-0.06	-0.20
developed open space	**-0.31**	-0.03	-0.21	-0.07	0.14	-0.14
cropland/agriculture	-0.09	0.09	-0.21	0.08	0.14	-0.01
hay pasture	-0.17	-0.11	0.24	**-0.47**	0.20	0.05
evidence of livestock use	0.01	-0.01	0.20	0.00	0.16	0.16

Table 7. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for Western Great Plains Saline Depression Wetland systems (n = 16). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	-0.14	**-0.45**	-0.20	0.17	0.15	-0.31
local road	0.09	0.06	0.02	0.00	**0.44**	0.04
developed open space	0.03	0.12	0.23	0.17	0.15	0.20
cropland/agriculture	-0.34	-0.21	-0.11	0.25	0.22	-0.28
evidence of livestock use	0.14	0.12	0.37	0.17	0.15	0.31

Level 2 attribute and overall condition scores were significantly correlated with multiple Level 3 vegetation metrics (Table 8). Specifically, the Biotic Composition and Structure attribute was significantly correlated with all vegetation metrics. Relative Size had a significant positive relationship with several FQI metrics. The Physicochemical attribute had a significant positive relationship with FQI of native species. Overall condition scores were significantly correlated with all vegetation metrics except the number of all species in a manner consistent with our expected relationships.

Table 8. Spearman's correlation coefficients for Level 2 attribute and overall condition scores and vegetation metrics for herbaceous depressional wetlands in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions (n = 32). Values in bold are significant at α ≤ 0.10.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
Mean C-value of native species	0.10	0.25	**0.57**	0.25	0.28	**0.45**
Mean C-value of all species	0.09	0.25	**0.65**	0.24	0.26	**0.48**
Number of exotic species	-0.17	-0.13	**-0.43**	-0.29	-0.20	**-0.35**
Number of native species	0.04	0.30	**0.56**	0.17	0.27	**0.44**
Number of all species	-0.09	0.19	**0.36**	0.07	0.24	0.27
Percent exotic species	-0.18	-0.26	**-0.64**	-0.30	-0.30	**-0.52**
Adjusted FQI of native species	0.13	**0.33**	**0.64**	0.29	0.29	**0.51**
Adjusted cover weighted FQI of native species	0.10	**0.34**	**0.66**	0.24	0.30	**0.52**
Cover weighted mean C-value of native species	0.05	0.25	**0.59**	0.17	0.27	**0.44**
Cover weighted mean C-value of all species	0.07	0.28	**0.62**	0.24	0.21	**0.45**
FQI	0.05	0.29	**0.64**	0.18	0.27	**0.47**
FQI of native species	0.06	**0.37**	**0.63**	0.21	**0.32**	**0.50**
Cover weighted FQI of all species	0.05	0.27	**0.62**	0.20	0.27	**0.48**
Cover weighted FQI of native species	0.04	**0.34**	**0.63**	0.18	0.31	**0.49**

The relationships between Level 2 scores and Level 3 vegetation metrics by Cowardin water regime revealed very different results. For temporary wetlands, the Landscape Context attribute was significantly correlated with several Level 3 vegetation metrics (Table 9), while only seasonal wetlands showed significant relationships between multiple vegetation metrics and the Biotic Structure and Composition attribute (Table 10). Semi-permanent wetlands showed only one significant relationship between the Hydrology attribute and the cover weighted mean C-value of all species (Table 11).

Table 9. Spearman's correlation coefficients for Level 2 attribute and overall condition scores and vegetation metrics for temporary wetlands in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions (n = 12). Values in bold are significant at α ≤ 0.10.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
Mean C-value of native species	0.33	0.15	0.35	0.34	0.37	0.44
Mean C-value of all species	**0.56**	-0.06	0.28	0.40	0.15	0.37
Number of exotic species	-0.43	0.00	-0.05	-0.26	0.09	-0.24
Number of native species	0.31	-0.03	0.45	0.22	0.13	0.13
Number of all species	0.09	-0.06	0.33	0.09	0.32	0.10
Percent exotic species	**-0.58**	0.08	-0.32	-0.40	-0.06	-0.27
Adjusted FQI of native species	**0.75**	0.13	0.46	**0.60**	0.19	**0.54**
Adjusted cover weighted FQI of native species	**0.60**	0.00	0.43	0.45	0.31	**0.50**
Cover weighted mean C-value of native species	0.15	-0.16	0.39	0.10	0.42	0.28
Cover weighted mean C-value of all species	**0.70**	0.02	0.43	**0.74**	0.19	**0.54**
FQI	**0.58**	-0.11	0.36	0.49	0.31	0.45
FQI of native species	0.37	0.11	0.52	0.30	0.23	0.30
Cover weighted FQI of all species	0.41	-0.11	0.43	**0.55**	0.22	0.38
Cover weighted FQI of native species	0.37	0.03	**0.53**	0.33	0.32	0.37

Table 10. Spearman's correlation coefficients for Level 2 attribute and overall condition scores and vegetation metrics for seasonal wetlands in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions (n = 11). Values in bold are significant at α ≤ 0.10.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
Mean C-value of native species	0.10	**0.52**	**0.99**	-0.03	0.01	0.49
Mean C-value of all species	-0.02	**0.67**	**0.95**	-0.03	0.01	0.48
Number of exotic species	-0.19	**-0.61**	**-0.95**	0.08	-0.04	**-0.58**
Number of native species	-0.19	**0.68**	**0.54**	-0.08	0.11	0.18
Number of all species	-0.46	0.45	0.06	-0.18	-0.06	-0.25
Percent exotic species	-0.11	**-0.69**	**-0.92**	0.08	-0.04	**-0.56**
Adjusted FQI of native species	-0.03	**0.67**	**0.95**	-0.11	-0.06	0.43
Adjusted cover weighted FQI of native species	0.10	**0.67**	**0.78**	-0.18	0.04	0.41
Cover weighted mean C-value of native species	0.03	0.37	0.46	-0.34	-0.21	0.06
Cover weighted mean C-value of all species	0.10	**0.52**	**0.65**	-0.34	-0.21	0.22
FQI	-0.08	**0.67**	**0.90**	-0.09	0.06	0.39
FQI of native species	-0.15	**0.67**	**0.80**	-0.09	0.06	0.29
Cover weighted FQI of all species	-0.10	**0.60**	0.47	-0.27	-0.11	0.10
Cover weighted FQI of native species	-0.06	**0.67**	**0.65**	-0.18	0.10	0.26

Table 11. Spearman's correlation coefficients for Level 2 attribute and overall condition scores and vegetation metrics for semi-permanent wetlands in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions (n = 9). Values in bold are significant at α ≤ 0.10.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
Mean C-value of native species	0.23	-0.55	-0.11	0.31	0.00	-0.04
Mean C-value of all species	-0.24	-0.55	0.31	0.10	0.14	-0.15
Number of exotic species	0.40	0.49	-0.11	-0.21	-0.49	0.52
Number of native species	0.08	-0.35	0.53	-0.32	-0.35	0.17
Number of all species	0.21	-0.28	0.41	-0.26	-0.41	0.25
Percent exotic species	0.45	0.48	-0.25	0.05	-0.41	0.56
Adjusted FQI of native species	-0.08	-0.55	-0.10	0.21	0.14	-0.38
Adjusted cover weighted FQI of native species	-0.04	-0.55	0.04	0.41	0.27	-0.28
Cover weighted mean C-value of native species	0.34	-0.55	-0.07	0.52	0.00	0.20
Cover weighted mean C-value of all species	0.03	-0.55	-0.11	**0.72**	0.14	-0.23
FQI	-0.13	-0.55	0.47	0.00	-0.27	0.01
FQI of native species	0.03	-0.41	0.28	-0.10	-0.27	0.03
Cover weighted FQI of all species	0.22	-0.55	0.43	0.21	-0.41	0.20
Cover weighted FQI of native species	0.11	-0.55	0.43	0.00	-0.27	0.11

We examined the relationship between our Level 1 metric scores and our Level 3 vegetation metrics and found no significant relationships. However, Level 3 vegetation metrics had several significant correlations with stressors observed both within the AA and within a 500-m envelope around the AA (Table 12). Nearly all Level 3 metrics were significantly correlated with hydrologic stressors in a direction that agreed with our expectations of vegetation responses to disturbance. Only the total number of species had no significant correlations. Within the AA, only exotic species were significantly related to observed stressors.

Table 12. Spearman's correlation coefficients for vegetation metrics and stressors observed at and around the wetland assessment area (AA) for wetlands in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions (n = 38). Values in bold are significant at α ≤ 0.10.

	Land Use	Transportation	Hydrology	Physicochemical	AA	Total Stressors
Mean C-value of native species	0.08	-0.01	**-0.46**	-0.12	-0.11	-0.19
Mean C-value of all species	0.03	-0.02	**-0.41**	-0.18	-0.20	-0.22
Number of exotic species	-0.02	0.17	**0.30**	0.16	**0.33**	**0.30**
Number of native species	0.08	0.09	**-0.35**	-0.16	0.04	-0.09
Number of all species	0.13	0.13	-0.22	-0.11	0.13	0.01
Percent exotic species	-0.02	0.10	**0.43**	0.23	**0.27**	**0.31**
Adjusted FQI of native species	0.04	-0.03	**-0.48**	-0.14	-0.16	-0.22
Adjusted cover weighted FQI of native species	0.01	0.00	**-0.42**	-0.26	-0.15	-0.25
Cover weighted mean C-value of native species	0.04	0.04	**-0.32**	-0.22	-0.16	-0.19
Cover weighted mean C-value of all species	-0.01	-0.07	**-0.28**	-0.17	-0.23	-0.20
FQI	0.00	0.05	**-0.39**	-0.21	-0.11	-0.18
FQI of native species	0.05	0.07	**-0.41**	-0.20	-0.05	-0.17
Cover weighted FQI of all species	0.01	0.06	**-0.30**	-0.19	-0.08	-0.13
Cover weighted FQI of native species	0.04	0.10	**-0.39**	-0.22	-0.06	-0.16

Examination of the relationship between stressors and Level 3 vegetation metrics by hydroperiod illustrates that significant relationships observed between hydrologic stressors and vegetation metrics is largely influenced by temporary wetlands (Table 13). For seasonal wetlands, only stressors observed within the AA were significantly correlated with Level 3 vegetation metrics (Table 14). For semi-permanent wetlands, it was largely the combination of all stressors that had a significant relationship with multiple Level 3 vegetation metrics (Table 15).

Table 13. Spearman's correlation coefficients for vegetation metrics and stressors observed at and around the wetland assessment area (AA) for temporary wetlands in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions (n = 12). Values in bold are significant at α ≤ 0.10.

	Land Use	Transportation	Hydrology	Physicochemical	AA	Total Stressors
Mean C-value of native species	0.21	-0.13	**-0.71**	0.00	0.07	-0.19
Mean C-value of all species	0.13	0.02	**-0.55**	0.23	0.12	0.10
Number of exotic species	-0.06	-0.09	0.20	-0.25	-0.25	-0.26
Number of native species	0.27	-0.33	0.02	0.22	-0.10	0.10
Number of all species	0.04	-0.32	0.05	-0.13	-0.25	-0.20
Percent exotic species	-0.17	0.22	0.21	-0.35	-0.07	-0.20
Adjusted FQI of native species	0.16	-0.28	**-0.61**	0.23	0.06	-0.01
Adjusted cover weighted FQI of native species	0.11	-0.14	**-0.54**	0.01	0.07	-0.08
Cover weighted mean C-value of native species	0.27	0.10	-0.47	-0.08	-0.15	-0.18
Cover weighted mean C-value of all species	-0.01	-0.42	-0.36	0.09	0.14	-0.05
FQI	-0.08	-0.19	**-0.50**	-0.03	-0.16	-0.20
FQI of native species	0.28	-0.34	-0.31	0.12	-0.06	-0.04
Cover weighted FQI of all species	0.00	-0.39	-0.25	-0.07	0.06	-0.14
Cover weighted FQI of native species	0.15	-0.17	-0.40	0.04	-0.22	-0.14

Table 14. Spearman's correlation coefficients for vegetation metrics and stressors observed at and around the wetland assessment area (AA) for seasonal wetlands in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions (n = 11). Values in bold are significant at α ≤ 0.10.

	Land Use	Transportation	Hydrology	Physicochemical	AA	Total Stressors
Mean C-value of native species	-0.40	-0.25	-0.19	-0.13	**-0.55**	-0.40
Mean C-value of all species	-0.40	-0.25	-0.19	-0.27	**-0.61**	-0.49
Number of exotic species	0.36	0.38	0.16	0.27	**0.66**	**0.55**
Number of native species	-0.30	-0.21	-0.16	-0.14	-0.09	-0.27
Number of all species	-0.20	0.03	0.07	0.04	0.29	0.09
Percent exotic species	0.36	0.38	0.16	0.30	**0.66**	**0.57**
Adjusted FQI of native species	-0.40	-0.28	-0.12	-0.14	-0.51	-0.40
Adjusted cover weighted FQI of native species	-0.50	-0.33	-0.05	-0.45	-0.51	**-0.54**
Cover weighted mean C-value of native species	-0.50	-0.18	0.24	-0.23	-0.21	-0.19
Cover weighted mean C-value of all species	-0.50	-0.31	0.19	-0.27	-0.37	-0.33
FQI	-0.50	-0.26	-0.12	-0.20	-0.50	-0.43
FQI of native species	-0.50	-0.19	-0.12	-0.20	-0.34	-0.35
Cover weighted FQI of all species	-0.40	-0.28	0.12	-0.18	-0.16	-0.25
Cover weighted FQI of native species	-0.50	-0.23	-0.05	-0.39	-0.35	-0.44

Table 15. Spearman's correlation coefficients for vegetation metrics and stressors observed at and around the wetland assessment area (AA) for semi-permanent wetlands in the Northwestern Great Plains and Northwestern Glaciated Plains ecoregions (n = 9). Values in bold are significant at α ≤ 0.10.

	Land Use	Transportation	Hydrology	Physicochemical	AA	Total Stressors
Mean C-value of native species	0.55	-0.27	0.14	0.11	0.52	0.49
Mean C-value of all species	0.55	-0.18	0.27	-0.3	0.45	0.23
Number of exotic species	-0.49	0.51	0.49	0.42	0.47	0.52
Number of native species	0.35	0.51	0.56	0	0.48	**0.63**
Number of all species	0.28	0.5	0.55	0.17	0.51	**0.72**
Percent exotic species	-0.48	0.23	0.14	0.45	0.35	0.36
Adjusted FQI of native species	0.55	-0.27	0.14	-0.15	0.29	0.19
Adjusted cover weighted FQI of native species	0.55	-0.55	-0.14	-0.22	0.13	-0.07
Cover weighted mean C-value of native species	0.55	-0.46	-0.14	**0.61**	0.28	**0.62**
Cover weighted mean C-value of all species	0.55	**-0.73**	-0.41	0.3	-0.12	0.06
FQI	0.55	0.18	0.41	-0.07	0.53	0.57
FQI of native species	0.41	0.27	0.55	0	**0.61**	**0.63**
Cover weighted FQI of all species	0.55	0.09	0.27	0.48	0.36	**0.79**
Cover weighted FQI of native species	0.55	0.18	0.41	0.07	0.53	**0.66**

The Level 2 attributes Landscape Context and Hydrology had significant negative relationships with nearly all Level 1 metrics (Table 16). The Level 1 metric score for local roads was significantly correlated with the Level 2 attributes Landscape Context, Biotic Composition and Structure, Hydrology, and Overall Wetland Condition. Additionally, low density development was significantly correlated with all Level 2 attributes except Physicochemical.

Table 16. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for herbaceous wetlands in the Middle, Canadian, and Northern Rockies ecoregions (n = 93). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	**-0.19**	**-0.53**	-0.07	**-0.21**	0.09	**-0.24**
local road	**-0.54**	-0.14	**-0.25**	**-0.41**	-0.12	**-0.52**
highway	**-0.21**	-0.05	0.11	**-0.18**	-0.13	-0.08
low density develoment	**-0.21**	**-0.44**	**-0.24**	**-0.18**	-0.09	**-0.23**
developed open space	-0.13	-0.05	-0.16	**-0.33**	-0.13	**-0.26**
hay pasture	**-0.23**	-0.14	-0.17	**-0.32**	-0.07	**-0.3**
canals/ditches	**-0.18**	-0.05	**-0.2**	**-0.23**	0.04	**-0.23**

Examination of the relationship between Level 1 metrics and Level 2 attributes by hydroperiod revealed that the Level 1 metric score for local roads had a significant negative relationship with the Level 2 attribute Landscape Context for all hydroperiods (Tables 17-20). The Level 1 metric score for four-wheel drive roads had a significant negative relationship with the Level 2 Relative Size attribute for all hydroperiods except semi-permanent wetlands, where correlation coefficients could not be calculated because all values for that attribute were the same. Overall wetland condition was significantly correlated with local roads for all hydroperiods except temporary wetlands.

Table 17. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for temporary wetlands in the Middle, Canadian, and Northern Rockies ecoregions (n = 14). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	**-0.46**	**-0.62**	-0.32	-0.15	0.26	-0.38
local road	**-0.72**	-0.25	**-0.50**	-0.21	0.27	-0.43
highway	-0.39	0.11	-0.04	-0.15	0.26	-0.03
low density develoment	**-0.46**	**-0.62**	-0.32	-0.15	0.26	-0.38
developed open space	-0.21	0.17	-0.13	-0.45	-0.16	-0.20
hay pasture	-0.36	-0.46	-0.34	-0.06	0.11	-0.41
canals/ditches	-0.26	-0.24	-0.19	0.07	0.29	-0.15
evidence of livestock use	0.13	0.17	0.06	-0.03	0.38	0.25

Table 18. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for saturated wetlands in the Middle, Canadian, and Northern Rockies ecoregions (n = 24). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	-0.25	**-0.80**	-0.07	-0.13	0.19	-0.26
local road	**-0.65**	-0.10	-0.16	**-0.36**	-0.09	**-0.51**
highway	-0.32	0.17	**0.53**	-0.24	-0.16	-0.01
developed open space	-0.18	0.11	0.10	-0.23	-0.22	-0.10
hay pasture	**-0.36**	0.14	0.15	**-0.48**	**-0.42**	-0.32
resource extraction	0.12	0.08	0.05	0.12	0.13	0.23
evidence of livestock use	-0.23	0.14	**-0.45**	-0.12	-0.10	-0.32

Table 19. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for seasonal wetlands in the Middle, Canadian, and Northern Rockies ecoregions (n = 33). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	-0.19	**-0.45**	-0.21	-0.28	0.13	-0.28
local road	**-0.44**	-0.22	**-0.30**	**-0.43**	-0.21	**-0.53**
highway	-0.10	**-0.30**	-0.28	**-0.31**	**-0.34**	-0.27
low density develoment	-0.23	**-0.48**	**-0.30**	-0.28	**-0.31**	**-0.30**
developed open space	-0.14	-0.17	**-0.40**	**-0.47**	-0.07	**-0.41**
hay pasture	-0.21	-0.11	**-0.37**	**-0.53**	0.14	**-0.36**
canals/ditches	-0.12	0.07	-0.21	-0.23	0.13	-0.15
upstream reservoir	0.22	0.07	0.28	0.13	-0.25	0.19
resource extraction	-0.12	-0.21	-0.25	-0.14	-0.22	-0.22
evidence of livestock use	-0.08	-0.06	0.08	-0.16	-0.08	-0.01

Table 20. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for semi-permanent wetlands in the Middle, Canadian, and Northern Rockies ecoregions (n = 22). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	0.02		0.05	-0.29	-0.31	-0.15
local road	**-0.56**		0.12	**-0.48**	**-0.37**	**-0.57**
canals/ditches	-0.30		-0.06	**-0.56**	-0.13	**-0.47**
resource extraction	**-0.37**		0.30	-0.23	0.13	-0.22

All wetland systems had significant negative relationships between the Level 1 metric local roads and the Level 2 attribute Landscape Context as well as Overall Wetland Condition. For Rocky Mountain Alpine-Montane Wet Meadows, all Level 2 attributes had significant negative correlations with at least one Level 1 metric (Table 21). Landscape Context, Relative Size, and

Hydrology attributes, as well as Overall Wetland Condition had significant negative relationships with several Level 1 metrics. All Level 2 attributes for Western North American Emergent Marshes had significant negative correlations with at least one Level 1 metric (Table 22). Again, Hydrology, Landscape Context, Relative Size, and Overall Wetland Condition were significantly correlated with several Level 1 metrics. Rocky Mountain Subalpine-Montane Fens showed few significant relationships between Level 1 metrics and Level 2 attributes, although each Level 2 attribute had at least one significant correlation with a Level 1 metric (Table 23).

Table 21. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for Rocky Mountain Alpine-Montane Wet Meadow systems in the Middle, Canadian, and Northern Rockies ecoregions (n = 60). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	-0.14	-0.17	-0.02	0.08	0.03	-0.10
local road	**-0.58**	**-0.22**	**-0.37**	**-0.36**	-0.01	**-0.54**
highway	**-0.34**	-0.18	0.02	**-0.41**	-0.12	**-0.27**
low density develoment	**-0.28**	**-0.30**	-0.05	**-0.40**	-0.20	**-0.30**
developed open space	-0.15	0.13	0.01	**-0.40**	**-0.25**	**-0.26**
hay pasture	**-0.28**	-0.05	-0.13	-0.16	-0.10	**-0.27**
canals/ditches	-0.21	**-0.22**	**-0.24**	-0.07	0.01	**-0.23**
upstream reservoirs	0.16	0.05	0.20	0.09	-0.18	0.13
resource extraction	-0.18	**-0.27**	-0.08	**-0.31**	-0.19	**-0.26**
evidence of livestock grazing	0.01	0.01	0.09	-0.01	0.01	0.07

Table 22. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for Western North American Emergent Marsh systems in the Middle, Canadian, and Northern Rockies ecoregions (n = 40). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	-0.15	**-0.49**	-0.16	**-0.36**	-0.05	**-0.29**
local road	**-0.44**	-0.04	-0.18	**-0.43**	-0.16	**-0.52**
highway	-0.11	0.05	-0.08	**-0.29**	**-0.31**	-0.19
developed open space	-0.20	**-0.49**	**-0.37**	**-0.32**	0.16	**-0.30**
hay pasture	-0.14	**-0.38**	**-0.39**	**-0.34**	0.03	**-0.29**
canals/ditches	**-0.29**	0.07	-0.18	**-0.49**	0.02	**-0.36**
resource extraction	**-0.27**	0.04	0.23	-0.20	0.11	-0.17
evidence of livestock grazing	0.14	-0.19	-0.03	0.17	0.00	0.12

Table 23. Spearman's correlation coefficients for Level 1 metric scores and Level 2 attribute and overall condition scores for Rocky Mountain Subalpine-Montane Fen systems in the Middle, Canadian, and Northern Rockies ecoregions (n = 20). Values in bold are significant at α ≤ 0.10. Due to lack of variability, Spearman's correlation coefficients could not be calculated for several Level 1 metric scores.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
4WD road	-0.04	**-0.55**	-0.16	-0.34	0.16	-0.14
local road	**-0.60**	-0.07	-0.33	-0.25	-0.11	**-0.49**
highway	-0.24	0.21	**0.54**	-0.26	-0.07	0.03
developed open space	-0.06	0.14	0.09	-0.25	-0.20	-0.07
hay pasture	-0.28	0.18	0.12	**-0.53**	**-0.41**	-0.32
canals/ditches	0.18	0.10	-0.24	0.13	0.16	0.10
resource extraction	0.18	0.10	0.00	0.13	0.16	0.26
evidence of livestock grazing	-0.19	0.14	**-0.40**	-0.25	-0.20	-0.29

Level 2 attribute and overall condition scores were significantly correlated with several Level 3 vegetation metrics (Table 24). Specifically, the Biotic Composition and Structure attribute was significantly correlated with all vegetation metrics. Landscape Context, Relative Size, and Hydrology also had a significant relationship with several FQI metrics. The Physicochemical attribute had a significant positive relationship with FQI of native species. Overall condition scores were significantly correlated with vegetation metrics in directions that were consistent with our expected relationships.

Table 24. Spearman's correlation coefficients for Level 2 attribute and overall condition scores and vegetation metrics for herbaceous wetlands in the Middle Rockies, Northern Rockies, and Canadian Rockies ecoregions (n = 37). Values in bold are significant at α ≤ 0.10.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
Mean C-value of native species	-0.12	0.02	**0.51**	0.25	0.27	0.26
Mean C-value of all species	0.09	0.19	**0.65**	**0.30**	0.24	**0.42**
Number of exotic species	**-0.42**	**-0.36**	**-0.39**	**-0.34**	-0.06	**-0.46**
Number of native species	**-0.29**	-0.13	**0.48**	0.09	0.25	0.14
Number of all species	**-0.33**	-0.21	**0.38**	0.04	0.24	0.06
Percent exotic species	**-0.35**	**-0.28**	**-0.61**	**-0.40**	-0.23	**-0.56**
Adjusted FQI of native species	-0.01	0.15	**0.62**	**0.29**	0.26	**0.37**
Adjusted cover weighted FQI of native species	-0.08	0.19	**0.51**	0.23	0.11	0.25
Cover weighted mean C-value of native species	-0.19	0.11	**0.41**	0.18	0.09	0.14
Cover weighted mean C-value of all species	-0.01	0.10	**0.68**	0.22	0.13	**0.31**
FQI	-0.19	-0.02	**0.63**	0.18	**0.32**	**0.29**
FQI of native species	**-0.29**	-0.11	**0.54**	0.17	**0.33**	0.20
Cover weighted FQI of all species	**-0.29**	-0.05	**0.65**	0.17	**0.28**	0.22
Cover weighted FQI of native species	**-0.30**	-0.03	**0.57**	0.17	**0.29**	0.20

The relationships between Level 2 scores and Level 3 vegetation metrics by Cowardin water regime revealed very different results. For temporary wetlands, all Level 2 attributes except Relative Size and Overall Wetland Condition were significantly correlated with at least two Level 3 vegetation metrics (Table 25). Saturated wetlands showed few significant relationships; only Biotic Composition and Structure and Hydrology were significantly correlated with Level 3 met-

rics, particularly those related to the presence of exotic species (Table 26). Seasonal wetlands showed significant relationships between multiple vegetation metrics and the Physicochemical attribute (Table 27). Semi-permanent wetlands showed significant relationships between the Hydrology attribute and multiple Level 3 metrics (Table 28).

Table 25. Spearman's correlation coefficients for Level 2 attribute and overall condition scores and vegetation metrics for temporary wetlands in the Middle Rockies, Northern Rockies, and Canadian Rockies ecoregions (n = 9). Values in bold are significant at α ≤ 0.10.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
Mean C-value of native species	0.39	-0.14	0.20	-0.01	-0.04	0.07
Mean C-value of all species	**0.90**	0.55	**0.70**	0.47	-0.08	**0.70**
Number of exotic species	**-0.91**	-0.56	-0.40	-0.03	0.38	-0.40
Number of native species	-0.08	0.14	0.54	**0.70**	0.58	**0.65**
Number of all species	-0.41	-0.14	0.25	**0.59**	**0.65**	0.34
Percent exotic species	**-0.92**	-0.56	**-0.59**	-0.37	0.11	**-0.63**
Adjusted FQI of native species	**0.82**	0.41	**0.75**	0.44	-0.12	**0.67**
Adjusted cover weighted FQI of native species	**0.78**	0.55	0.34	0.06	-0.43	0.33
Cover weighted mean C-value of native species	0.50	0.55	0.01	-0.21	**-0.61**	-0.02
Cover weighted mean C-value of all species	**0.73**	0.27	**0.63**	0.21	-0.38	0.43
FQI	**0.66**	0.41	**0.67**	**0.61**	0.24	**0.73**
FQI of native species	0.12	0.14	0.56	**0.66**	0.46	**0.58**
Cover weighted FQI of all species	0.38	0.27	**0.70**	0.44	-0.07	0.57
Cover weighted FQI of native species	0.22	0.41	**0.64**	**0.77**	0.31	**0.67**

Table 26. Spearman's correlation coefficients for Level 2 attribute and overall condition scores and vegetation metrics for saturated wetlands in the Middle Rockies, Northern Rockies, and Canadian Rockies ecoregions (n = 13). Values in bold are significant at α ≤ 0.10.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
Mean C-value of native species	-0.06	0.17	0.36	0.43	0.27	0.33
Mean C-value of all species	0.02	0.23	0.38	0.42	0.19	0.35
Number of exotic species	-0.22	-0.30	-0.44	**-0.52**	-0.18	**-0.53**
Number of native species	-0.27	-0.12	0.22	-0.27	0.08	-0.14
Number of all species	-0.23	-0.14	0.08	-0.35	0.02	-0.22
Percent exotic species	-0.15	-0.24	**-0.53**	-0.45	-0.32	**-0.55**
Adjusted FQI of native species	-0.06	0.17	0.36	0.43	0.27	0.33
Adjusted cover weighted FQI of native species	-0.12	0.00	0.37	**0.49**	0.14	0.21
Cover weighted mean C-value of native species	-0.13	-0.06	0.35	**0.49**	0.09	0.16
Cover weighted mean C-value of all species	-0.14	0.06	0.36	0.43	0.13	0.21
FQI	-0.20	0.06	**0.55**	-0.04	0.19	0.13
FQI of native species	-0.25	-0.06	0.44	-0.06	0.17	0.03
Cover weighted FQI of all species	-0.22	0.11	**0.60**	0.05	0.17	0.15
Cover weighted FQI of native species	-0.21	0.06	**0.63**	0.05	0.16	0.15

Table 27. Spearman's correlation coefficients for Level 2 attribute and overall condition scores and vegetation metrics for seasonal wetlands in the Middle Rockies, Northern Rockies, and Canadian Rockies ecoregions (n = 10). Values in bold are significant at α ≤ 0.10.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
Mean C-value of native species	0.34	0.29	0.25	0.50	**0.80**	**0.61**
Mean C-value of all species	0.51	0.41	0.53	0.44	**0.77**	**0.77**
Number of exotic species	-0.47	-0.54	-0.32	-0.10	-0.20	-0.40
Number of native species	0.00	-0.06	0.44	**0.56**	0.33	0.35
Number of all species	-0.05	-0.29	0.32	**0.59**	0.27	0.24
Percent exotic species	-0.41	-0.53	**-0.73**	-0.41	-0.46	**-0.69**
Adjusted FQI of native species	0.45	0.41	0.45	0.44	**0.73**	**0.70**
Adjusted cover weighted FQI of native species	0.04	0.41	0.11	0.31	**0.63**	0.42
Cover weighted mean C-value of native species	-0.05	0.41	-0.05	0.25	**0.55**	0.30
Cover weighted mean C-value of all species	0.07	0.17	**0.68**	0.37	0.51	0.53
FQI	0.13	0.17	0.38	0.44	**0.60**	0.50
FQI of native species	0.13	-0.06	0.33	0.50	**0.55**	0.44
Cover weighted FQI of all species	-0.12	0.17	0.44	0.44	0.55	0.41
Cover weighted FQI of native species	-0.18	0.17	0.20	0.44	0.54	0.31

Table 28. Spearman's correlation coefficients for Level 2 attribute and overall condition scores and vegetation metrics for semi-permanent wetlands in the Middle Rockies, Northern Rockies, and Canadian Rockies ecoregions (n = 5). Values in bold are significant at α ≤ 0.10.

	Landscape Context	Relative Size	Biotic Composition and Structure	Hydrology	Physicochemical	Overall Condition
Mean C-value of native species	-0.29		-0.69	-0.30	-0.73	**-0.87**
Mean C-value of all species	0.55		0.11	0.00	-0.36	-0.15
Number of exotic species	-0.50		-0.46	**-0.89**	0.00	-0.67
Number of native species	-0.50		-0.46	**-0.89**	0.00	-0.67
Number of all species	-0.50		-0.46	**-0.89**	0.00	-0.67
Percent exotic species	-0.76		-0.80	-0.59	-0.36	**-0.87**
Adjusted FQI of native species	-0.03		-0.34	-0.59	-0.36	-0.67
Adjusted cover weighted FQI of native species	-0.36		-0.67	-0.29	-0.71	**-0.90**
Cover weighted mean C-value of native species	-0.36		-0.67	-0.29	-0.71	**-0.90**
Cover weighted mean C-value of all species	-0.21		-0.22	**-0.87**	0.00	-0.60
FQI	-0.50		-0.46	**-0.89**	0.00	-0.67
FQI of native species	-0.50		-0.46	**-0.89**	0.00	-0.67
Cover weighted FQI of all species	-0.56		-0.45	**-0.87**	0.00	-0.70
Cover weighted FQI of native species	-0.56		-0.45	**-0.87**	0.00	-0.70

We examined the relationship between our Level 1 metric scores and our Level 3 vegetation metrics and found no significant relationships. However, Level 3 vegetation metrics had several significant correlations with stressors observed within a 500-m envelope around the AA in a direction that agreed with our expectations of vegetation responses to disturbance, but stressors observed within the AA were not significantly correlated with any Level 3 metric (Table 29).

Table 29. Spearman's correlation coefficients for vegetation metrics and stressors observed at and around the wetland assessment area for wetlands in the Middle Rockies, Northern Rockies, and Canadian Rockies ecoregions (n = 37). Values in bold are significant at α ≤ 0.10.

	Land Use	Transportation	Hydrology	AA	Total Stressors
Mean C-value of native species	0.24	-0.23	-0.10	0.01	**-0.36**
Mean C-value of all species	0.16	**-0.40**	-0.23	-0.03	**-0.31**
Number of exotic species	0.15	**0.48**	**0.40**	-0.07	0.05
Number of native species	**0.31**	0.04	0.07	-0.21	-0.24
Number of all species	**0.29**	0.14	0.12	-0.22	-0.21
Percent exotic species	0.10	**0.53**	**0.43**	0.15	0.24
Adjusted FQI of native species	0.21	**-0.34**	-0.17	-0.01	**-0.34**
Adjusted cover weighted FQI of native species	0.26	-0.17	-0.24	0.10	-0.26
Cover weighted mean C-value of native species	**0.29**	-0.03	-0.19	0.14	-0.23
Cover weighted mean C-value of all species	0.14	**-0.34**	-0.08	-0.10	**-0.29**
FQI	**0.32**	-0.14	-0.04	-0.13	**-0.32**
FQI of native species	**0.33**	-0.04	0.04	-0.16	**-0.33**
Cover weighted FQI of all species	**0.30**	-0.08	0.01	-0.15	**-0.36**
Cover weighted FQI of native species	**0.33**	-0.02	-0.01	-0.12	**-0.34**

The relationships between Level 3 vegetation metrics and stressors varied with hydroperiod. Several vegetation metrics were significantly correlated with stressors related to both Transportation and Hydrology in temporary wetlands (Table 30). Saturated wetlands had no significant correlations between Level 3 vegetation metrics and stressors (Table 31). Vegetation metrics for seasonal wetlands related to exotic species, C-values, and FQI metrics were significantly correlated with each stressor category (Table 32). Semi-permanent wetlands had results contrary to our initial predictions regarding vegetation responses to disturbance, as several vegetation metrics were significantly, positively correlated with hydrologic stressors, although the sample size was small (n = 5; Table 33).

Table 30. Spearman's correlation coefficients for vegetation metrics and stressors observed at and around the wetland assessment area for temporary wetlands in the Middle Rockies, Northern Rockies, and Canadian Rockies ecoregions (n = 9). Values in bold are significant at α ≤ 0.10. Correlation coefficients for Land Use could not be calculated because there was no variability in values.

	Land Use	Transportation	Hydrology	AA	Total Stressors
Mean C-value of native species		-0.46	-0.10	-0.31	-0.41
Mean C-value of all species		**-0.82**	**-0.62**	-0.52	**-0.94**
Number of exotic species		**0.86**	0.58	0.16	**0.80**
Number of native species		0.09	0.00	-0.32	-0.10
Number of all species		0.42	0.21	-0.32	0.18
Percent exotic species		**0.84**	**0.63**	0.53	**0.95**
Adjusted FQI of native species		**-0.87**	-0.41	-0.52	**-0.89**
Adjusted cover weighted FQI of native species		**-0.64**	**-0.62**	-0.21	**-0.69**
Cover weighted mean C-value of native species		-0.32	-0.52	0.21	-0.30
Cover weighted mean C-value of all species		**-0.91**	-0.21	-0.41	**-0.80**
FQI		-0.55	-0.52	**-0.62**	**-0.78**
FQI of native species		-0.09	-0.10	-0.41	-0.28
Cover weighted FQI of all species		-0.50	-0.10	-0.31	-0.49
Cover weighted FQI of native species		-0.09	-0.31	-0.41	-0.37

Table 31. Spearman's correlation coefficients for vegetation metrics and stressors observed at and around the wetland assessment area for saturated wetlands in the Middle Rockies, Northern Rockies, and Canadian Rockies ecoregions (n = 13). Values in bold are significant at α ≤ 0.10.

	Land Use	Transportation	Hydrology	AA	Total Stressors
Mean C-value of native species	0.06	0.11	-0.27	0.32	0.21
Mean C-value of all species	0.06	0.06	-0.21	0.38	0.21
Number of exotic species	0.02	0.06	0.17	-0.39	-0.16
Number of native species	0.03	0.38	-0.07	-0.22	-0.02
Number of all species	0.02	0.34	0.01	-0.27	-0.05
Percent exotic species	0.04	-0.09	0.20	-0.28	-0.13
Adjusted FQI of native species	0.06	0.11	-0.27	0.32	0.21
Adjusted cover weighted FQI of native species	0.03	0.23	-0.23	0.21	0.16
Cover weighted mean C-value of native species	0.05	0.23	-0.19	0.21	0.18
Cover weighted mean C-value of all species	0.09	0.28	-0.12	0.27	0.25
FQI	0.11	0.40	-0.10	0.01	0.14
FQI of native species	0.07	0.40	-0.16	-0.05	0.08
Cover weighted FQI of all species	0.09	0.40	-0.16	-0.02	0.11
Cover weighted FQI of native species	0.09	0.40	-0.11	-0.06	0.11

Table 32. Spearman's correlation coefficients for vegetation metrics and stressors observed at and around the wetland assessment area for seasonal wetlands in the Middle Rockies, Northern Rockies, and Canadian Rockies ecoregions (n = 10). Values in bold are significant at α ≤ 0.10.

	Land Use	Transportation	Hydrology	AA	Total Stressors
Mean C-value of native species	-0.30	-0.54	-0.27	-0.39	-0.48
Mean C-value of all species	-0.52	**-0.58**	-0.34	**-0.58**	**-0.67**
Number of exotic species	**0.67**	0.26	0.43	0.00	0.46
Number of native species	0.33	-0.31	-0.34	-0.19	-0.11
Number of all species	0.39	-0.20	-0.19	-0.16	0.00
Percent exotic species	0.47	0.36	**0.69**	0.39	0.55
Adjusted FQI of native species	-0.44	-0.54	-0.34	-0.51	-0.58
Adjusted cover weighted FQI of native species	0.06	-0.18	**-0.57**	-0.06	-0.13
Cover weighted mean C-value of native species	0.19	-0.04	**-0.57**	0.07	0.03
Cover weighted mean C-value of all species	-0.28	-0.31	-0.34	**-0.73**	-0.48
FQI	0.14	-0.54	-0.27	-0.34	-0.32
FQI of native species	0.17	-0.49	-0.11	-0.34	-0.27
Cover weighted FQI of all species	0.06	-0.31	-0.42	-0.43	-0.28
Cover weighted FQI of native species	0.28	-0.27	-0.42	-0.18	-0.10

Table 33. Spearman's correlation coefficients for vegetation metrics and stressors observed at and around the wetland assessment area for semi-permanent wetlands in the Middle Rockies, Northern Rockies, and Canadian Rockies ecoregions (n = 5). Values in bold are significant at α ≤ 0.10.

	Land Use	Transportation	Hydrology	AA	Total Stressors
Mean C-value of native species	0.69	0.11	0.30	0.65	0.76
Mean C-value of all species	-0.11	-0.65	0.00	0.70	0.03
Number of exotic species	0.46	0.43	**0.89**	-0.11	0.55
Number of native species	0.46	0.43	**0.89**	-0.11	0.55
Number of all species	0.46	0.43	**0.89**	-0.11	0.55
Percent exotic species	0.80	0.65	0.59	0.05	**0.82**
Adjusted FQI of native species	0.34	-0.11	0.59	0.49	0.50
Adjusted cover weighted FQI of native species	0.67	0.21	0.29	0.74	**0.82**
Cover weighted mean C-value of native species	0.67	0.21	0.29	0.74	**0.82**
Cover weighted mean C-value of all species	0.22	0.16	**0.87**	0.21	0.46
FQI	0.46	0.43	**0.89**	-0.11	0.55
FQI of native species	0.46	0.43	**0.89**	-0.11	0.55
Cover weighted FQI of all species	0.45	0.53	**0.87**	0.00	0.62
Cover weighted FQI of native species	0.45	0.53	**0.87**	0.00	0.62

Comparison of Montana DEQ Rapid Wetland Assessment and MTNHP RAM and Level 3 Scores

We completed 33 Montana DEQ Rapid Wetland Assessments, all of which were completed in depressional wetlands. All Level 2 attribute scores and Overall Wetland Condition scores from the MTNHP RAM were significantly correlated with Montana DEQ Rapid Wetland Assessment scores except for the Montana DEQ Water Quality score (Table 34).

We collected vegetation data at 24 of these sites. MTDEQ Rapid Wetland Assessment scores had several strong, significant correlations with multiple Level 3 vegetation metrics (Table 35). Only the number of all species was not related to any Rapid Assessment scores.

Table 34. Spearman's correlation coefficients for Montana DEQ Rapid Wetland Assessment scores and the MTNHP Level 2 Rapid Assessment scores (n = 33). Values in bold are significant at α ≤ 0.10.

	Overall Condition	Hydrology	Landscape Context	Biotic Composition and Structure	Physicochemical
Overall Condition	**0.82**	**0.46**	**0.53**	**0.58**	**0.71**
Hydrologic Condition	**0.48**	**0.33**	0.25	0.22	**0.65**
Stressors/Buffer	**0.78**	**0.44**	**0.48**	**0.48**	**0.71**
Biotic Condition	**0.63**	**0.34**	0.26	**0.65**	**0.49**
Water Quality	0.11	-0.11	0.02	0.14	0.12

Table 35. Spearman's correlation coefficients for Montana DEQ Rapid Wetland Assessment scores and Level 3 vegetation metrics (n = 24). Values in bold are significant at α ≤ 0.10.

	Hydrologic Condition	Biotic Condition	Water Quality	Stressors/ Buffer	Wetland Impact Score	Overall Condition
Mean C-value of native species	**0.71**	**0.45**	0.33	**0.69**	**0.74**	**0.73**
Mean C-value of all species	**0.58**	**0.62**	0.30	**0.62**	**0.71**	**0.69**
Number of exotic species	**-0.40**	**-0.70**	-0.17	**-0.55**	**-0.65**	**-0.65**
Number of native species	0.31	0.32	0.34	**0.39**	**0.42**	**0.39**
Number of all species	0.14	-0.06	0.22	0.13	0.09	0.05
Percent exotic species	**-0.52**	**-0.64**	-0.20	**-0.61**	**-0.70**	**-0.68**
Adjusted FQI of native species	**0.60**	**0.58**	**0.37**	**0.65**	**0.74**	**0.74**
Adjusted cover weighted FQI of native species	**0.50**	**0.46**	0.28	**0.49**	**0.56**	**0.54**
Cover weighted mean C-value of native species	**0.47**	0.21	0.12	**0.38**	**0.40**	**0.37**
Cover weighted mean C-value of all species	0.33	**0.47**	0.11	**0.45**	**0.47**	**0.42**
FQI	**0.49**	**0.49**	**0.38**	**0.54**	**0.60**	**0.58**
FQI of native species	**0.53**	**0.43**	0.34	**0.54**	**0.60**	**0.58**
Cover weighted FQI of all species	0.32	**0.39**	0.23	**0.42**	**0.41**	**0.36**
Cover weighted FQI of native species	**0.46**	**0.36**	**0.37**	**0.46**	**0.50**	**0.47**